[UNIVERSITY OF LONDON]

WYE COLLEGE

Department of Hop Research

ANNUAL REPORT

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DEPARTMENT OF HOP RESEARCH

Introduction

The College is particularly grateful to Mr. F. C. Thompson, who for the past year has so ably discharged all the additional duties which have fallen to his lot as Acting Head of the Department since the retirement of Dr. A. H. Burgess. Mr. Harry Darling, B.Sc., M.Agric. (Belfast), A.I.C.T.A. has recently taken up his duties as Head of the Department and a very warm welcome is extended to him. Although he is as yet unfamiliar with the hop plant, he has had considerable experience in working with other specialized economic crop plants and will bring to the work of the Department a highly trained, fresh mind and wide experience in the biological field. Prior to his new appointment at Wye, he was Senior Lecturer in Zoology at the University College of Khartoum.

We also extend a welcome to Mr. R. A. Neve, B.Sc.Agric. (Reading), Dip. Agric. Sci.(Cantab.), who took up his duties in the Department in April, 1953, as Plant Breeder in succession to Dr. S. O. S. Dark. Although there was some gap between Dr. Dark's departure and the arrival of Mr. Neve there was no break in the routine of the plant breeding work since the work was ably carried out during the interregnum by Mr. R. Farrar. Mr. Weston, B.Sc.(Lond.), A.R.C.S. joined the staff of the Department in March, 1953, to assist in the work of the Chemistry Section of the Department. Save for the pressing need for assistance in the field of pathology the research team is once again complete and equipped to develop the envisaged programme of work.

During the year the extensions to the new Research Laboratory were completed, thus making it possible to bring the whole of the research team together once again to work in a single building well provided with the necessary specialist technical equipment. For some time past the difficulties of the Department had been considerably increased by the enforced separation resulting from part of the work being carried out in the Guinness Laboratory and part in the partially completed new research laboratory. The completion of the new laboratory has also made it possible to free the Guinness Laboratory for other pressing research work.

The extensions to the oast at Coldharbour were also completed

and the four new kilns were in partial operation for the 1953 crop. It is intended to convert, during the coming summer, the two steam heated kilns of the Coldharbour oast to direct oil-firing. During the last winter considerable modifications were carried out to the nursery garden, which has been radically re-planned to meet the requirements of the programme of plant breeding work. It is considered that the general equipment of the Department is now in good order and substantially adequate to meet the immediate requirements of the research programme, though it is fair to assume that the new director of the Department will hope to see further developments in the field of applied biological research.

The College is again deeply appreciative of the continued co-operation and interest which it receives from the growers, the Hops Marketing Board, the Brewing Industry Research Foundation, and from its closely associated colleagues at the East Malling Research Station. In particular it desires to express its very grateful thanks for the substantial grants which have been made available to its hop research work, through the Ministry of Agriculture, from the Hops Marketing Board and the Institute of Brewing.

DUNSTAN SKILBECK,
Principal.

May, 1954.

GENERAL REPORT

This general introductory report on the progress of experimental work in the Department during the past year offers an opportunity to review developments in hop research in recent years, and to discuss the lines along which it is hoped such work can be developed in the next five year period.

The Department came into existence in 1947-48 and was placed in charge of Dr. Burgess who for many years prior to 1939 had made valuable contributions to hop research in a wide field, but particularly in the sphere of hop drying. In addition, at Wye, Professor Salmon had done notable work in the field of plant breeding, resulting in the production of a range of new varieties of hops, some of which have now found an important place on the market and in the export trade.

Progress of the work in the early years of the Department was restricted by the need to recruit scientific staff of suitable qualifications and experience, and the provision of adequate laboratory accommodation. A new laboratory was completed in the latter part of 1949 by which time a nucleus of trained staff had been established. Several lines of research were then initiated under the general direction of Dr. Burgess, and some of these are now beginning to bear fruit. The development of the work of the Department can conveniently be taken under the following headings:

Plant Breeding

The aims of our plant breeding programme may be summarized as follows:

1. The production of hops to replace imported American hops.

This has been the aim of much of Professor Salmon's work, and has resulted in the production of two varieties namely Bullion (Q43) and Brewer's Gold (C9*a*), which are now generally acceptable on the market as substitutes for American hops.

2. The development of commercially acceptable varieties which are tolerant (resistant) to *Verticillium* Wilt and other important hop diseases.

Certain of the varieties bred by Professor Salmon have been found, by chance, to be tolerant to *Verticillium* Wilt and, in parti-

cular, the variety OR55 (Keyworth's Midseason) is now grown on a wide scale in Wilt infected areas. This variety, however, is not generally popular with brewers and a search for a more suitable variety continues. Bramling Cross (OT48) is another of the varieties bred by Professor Salmon which shows appreciable tolerance (resistance) to *Verticillium* Wilt and is more acceptable to the brewers than OR55. It is now beginning to be planted up on a fairly large scale.

In the last three to four years, however, a new approach has been initiated in the plant breeding section at Wye, where an attempt is now being made to breed definitely for Wilt tolerance by large scale controlled crosses of male and female hops possessing known tolerance to the disease.

A further development is the production of polyploid hops. By this process it is hoped to "double-up" the characteristics of English aroma and other desirable qualities on the female side, so that they are not swamped by less desirable qualities when crossed with male hops possessing disease resistant factors. The resultant triploid hops should have additional advantages in being largely seedless and less liable to cone shatter—the latter an important point in connection with machine picking.

3. The production of hop varieties which will be valued on the market higher than the Fuggle variety, and which can be grown on at least the better type of Fuggle soil.

These aims have to some extent been met by the breeding work which has gone on to produce American substitute hops, since one of the features of this type of hop is its high preservative value (resin content). By using American strains crossed with accepted English commercial varieties of high quality, Salmon has produced such hops as Northern Brewer and John Ford which are accepted by brewers as English type hops. Such hops are valued higher than Fuggle, the two named actually being graded as Goldings on account of their good commercial qualities. It has already been found that certain of these new varieties can be grown on the better type of Fuggle soil.

4. The production of hop varieties which pick well by machine.

This aim has already been met to some extent, by chance, in that many of the hop varieties bred by Salmon have the characteristic of dense, tough cones which pick well by machine and do not shatter to anything like the extent as does, say, Fuggle.

To summarize then, the main lines of our breeding programme are the production of hop varieties which are, (*a*) resistant to disease, particularly *Verticillium* Wilt, (*b*) good machine pickers and (*c*) of higher commercial valuation than the Fuggle.

Hop Nutrition and Manuring

When the Department was started it was decided that there was a definite need for critical fertilizer experiments, particularly to study the interaction of nutritional factors in the growth of hops and to gain knowledge about the optimum levels of nutrients required for maximum growth and yield under varying conditions; also the effect of manurial treatment on the resin content of the cones.

In commercial practice, hops receive very heavy applications of fertilizer and while the plant responds to heavy manuring, there is the possibility that excessive and unbalanced manuring may lead to induced deficiency disorders and result in weakened growth and loss of crop. In addition, though at one time it was thought that the cost of manuring was a relatively small item in the general cost of production of hops, in actual fact at the present time it does form a large item, and any information which may lead to a lowering of such costs, while maintaining crop yield, should be of value.

The following conclusions can be drawn from experiments and field observations made over the past three to four years:

(*a*) The level of nitrogen manuring should be of the order of 300 lb. N per acre, as originally recommended by Dr. Burgess.

(*b*) Where the level of available phosphate in the soil is high the heavy applications of phosphate frequently given are unnecessary and could be reduced to a much more economic level.

(*c*) Potash deficiency is the commonest manurial deficiency found in hops, emphasizing the need for building up and maintaining a very high level of available potash in the soil. This may mean applying heavier applications than are sometimes given.

(*d*) Although magnesium deficiency symptoms are frequently seen in hops, particularly towards the end of the growing season, it is only in the case of severe deficiency resulting in an early and extensive defoliation, that an appreciable reduction in crop results.

(*e*) That hops can grow well at a lower soil pH than was at one time thought, and a pH range of 5·5 to 6·0 is now recommended. Where the calcium (lime) content of the soil is very high there is evidence that the uptake of potash by the plant is suppressed, so that growing hops at a lower pH than has been previously recommended should tend to increase potash up-take.

(*f*) There is no evidence to date that trace elements are of importance in hop nutrition under field conditions, with the exception of one or two cases of suspected boron deficiency in the West Midland hop growing area.

(*g*) The experiments so far carried out have not shown that

manurial treatment has any influence on resin production, under field conditions.

Growth of Hops in Grass Swards

Many growers are now finding difficulty in obtaining sufficient quantities of farmyard manure or other bulky organic manures, to keep up a satisfactory humus content in soil which is in continuous cultivation under hops. Among alternative methods of building up the humus in soils, the establishment of grass/clover swards has been found to be the best and it was, therefore, considered desirable to investigate the possibilities of growing hops in grass.

The results obtained from the trials so far carried out, show that the most promising seeds mixture for sowing down is S50 timothy and S100 clover. Also that if the sward is well managed, the grass kept really short by close mowing or a combined mowing and grazing technique, and adequate nitrogenous manuring given, then satisfactory growth of the hops can result and give a crop at least equal to that grown under comparable conditions of arable cultivation.

Organic Constituents of the Hop Plant

Preliminary investigations have been carried out on the application of chromatographic techniques to the analysis of the hop plant, in particular being directed to the problem of the method of biosynthesis of the hop resins.

Alcoholic extracts of hop leaves and cones have been subjected to a fractionation involving the use of ion exchange resins, and the resulting fractions separated into their components by paper chromatography. In this way variations in the composition of the plant can be followed during its growth. The phenolic fraction, or fraction which is extracted from an aqueous solution by ethyl acetate, shows the greatest variation both between varieties and during the season and on this account seems a promising field for further study.

Hop Drying

The majority of commercial drying practice is now based on the findings and recommendations made by Dr. Burgess as a result of his researches carried out from 1920 up to 1939. These findings have placed hop drying on a scientific basis, but with the introduction of machine picking new factors have arisen in drying due to the higher proportion of broken hops found in machine picked samples. Owing to the marked difference in drying rates between whole and broken

hops, a sample containing an appreciable proportion of the latter can dry very unevenly and make it very difficult for the drier to assess when the hops are ready to take off.

Experiments are being carried out at Wye using different temperatures and air-speeds during drying, to try and find the best conditions for drying machine picked hops. In further experiments methods for shortening the drying time of hops, and the use of sulphur dioxide gas as a bleaching agent in place of burning roll sulphur, are being investigated. The experimental samples produced undergo market evaluation and brewing trials. A fuller account of these experiments is given on page 13.

Machine Picking

For the past three years the Department has been responsible for co-ordinating a survey of hop picking machines, carried out by the Advisory Officers of the N.A.A.S. with the help of staff, and of student labour, from Wye College. The work has been largely done in the West Midlands, where the majority of the machines are located, and the main responsibility for organizing the survey has fallen on Mr. Chater, the Hops Advisory Officer in that area.

Much useful information has been obtained on the most efficient forms of labour and transport organization for bringing the hops to the machine. On the machine itself investigations on wastage, breakage of the cones and resin losses have been made with a view to improving the final sample of hops produced. A full report on the latest stages of the investigation is given on page 63. The information gained by the surveys carried out during the past three years is at present being summarized. This summary will be published later.

Cultural Experiments

One of the most interesting experiments in progress is one laid down in 1951 to investigate the effects of different heights of wirework and different widths of spacing on the growth and yield of four varieties of hops—Fuggle, John Ford, Bullion and Brewer's Gold. The main object is to produce the type of growth most favourable for machine picking combined with satisfactory yield. High wirework and wide spacing definitely favour this type of growth, by producing hops spaced along the bine and avoiding the development of dense, tangled heads. Wider spacing, however, results in a smaller number of hills per acre, and obviously means that a very much heavier crop per hill must be produced to keep up the yield per acre.

So far the weaker growing varieties, Fuggle and John Ford, have cropped surprisingly well at the medium height and spacing of 15 ft. and 7 ft. sq., respectively, while the strong growing varieties, Bullion and Brewer's Gold do very well at the maximum height of 17 ft. 3 in., but have not yet been able to produce maximum crop on the widest spacing of 7½ ft. square. A progress report on this experiment appears on page 23.

A study is being made of different clonal stocks of Golding and Fuggle hops, with a view to selecting those showing the best cropping performance allied to high preservative value and other desirable qualities. In addition, particular attention is being paid to selecting early, mid-season and late clones of both Golding and Fuggle types so as to enable the hops to be harvested in the best condition over a fairly wide picking season, as is desirable when machine picking.

A further cultural experiment in progress is concerned with the effect on crop yield of cutting the bine at picking time, as compared with allowing the bine to ripen off before cutting in about November. The former is the usual procedure when machine picking. So far the experiment at Wye has not shown any difference in yield between the two treatments.

The Hop Crop

The hop acreage at Wye (some 20 acres) is at present all down to plant breeding investigations or cultural experiments. Much of the acreage concerned with plant breeding experiments cannot be regarded as under commercial cropping owing to the necessity for continual grubbing and replanting; the cultural experiments, however, are grown as a commercial crop as far as the treatments applied permit. In 1953, in spite of severe attacks of Downy Mildew throughout the growing season which could only be kept under control by continual treatment with copper sprays, some very useful crops were grown, ranging from 25 cwt. per acre in the case of Fuggle to well over 30 cwt. per acre in the case of the heavy yielding new variety Bullion.

Great credit is due to the field staff responsible for growing the hops, and in particular to Mr. J. Ashby, the Hops Foreman.

General

Close liaison has been maintained with the Institute of Brewing, the Brewing Industry Research Foundation and the Hops Marketing

Board. The Department looks forward to closer co-operation with the Foundation in connection with brewing trials of some of the samples of hops produced from the various experiments.

The Department also works in close co-operation with the National Agricultural Advisory Service and East Malling Research Station. In particular, the Hops Advisory Officers of the N.A.A.S. form a channel through which the results of experiments can be passed to growers, and the research at Wye, into the production of *Verticillium* Wilt tolerant varieties of hops is carried out in collaboration with the staff of the Plant Pathology Department at East Malling.

Visits have been paid to the Rosemaund Experimental Husbandry Farm, Hereford, where a full programme of hop experiments is now established. The Department has co-operated in the work by carrying out leaf analysis on 64 samples from a factorial manurial experiment, and resin analysis on hop samples from variety trial plots.

In July, members of the British Grassland Society meeting at Wye for their annual conference in 1953, were shown round the experimental plots of grassed-down hops established at Bodiam, Sussex, through the kind co-operation of Messrs. Arthur Guinness, Son & Co., Ltd.

In August, Mr. F. C. Thompson attended, as a delegate of the Hops Marketing Board, the Annual Conference of the Scientific Commission of the European Hops Cultivation Committee. The conference was held in Germany, at Munich, and visits were paid to the well-known Hallertau district of Bavaria to study experimental work in progress and to observe hops growing under commercial conditions.

A successful "Open Day" was held on 9th September when the Association of Growers of the New Varieties of Hops visited the College for their Annual Hop Walk, and a party of some 70 people, including representatives of all sides of the hop industry, spent the afternoon seeing the experiments in progress in Wye Field Hop Garden. After tea at Withersdane Hall, those of the party who were able to stay on had an opportunity of visiting the experimental laboratories.

A talk on "Recent Developments in Hop Research" was given to a conference of growers in Hereford, in November, by F. C. Thompson. The Department was also represented at a conference of Hampshire hop growers, when papers were read by F. C. Thompson and G. A. Watson, on "Hop Nutrition and Manuring" and "Recent

Experimental Work on Hop Drying" respectively. Messrs Neve and Beard have given talks to Young Farmers' Clubs.

Acknowledgments

As stated above, the hop acreage at Wye is at present devoted to plant breeding investigations or cultural experiments. In consequence, for other experimental work, facilities have to be sought on growers farms. Grateful thanks are due to A. J. Large, Cherry Gardens, Goudhurst, on whose land a series of manurial deficiency plots are established, to Mrs. D. J. Roberts, Moons Farm, Piltdown, where the Department has had a magnesium deficiency experiment running for several years, and to a number of growers who have established trial plots of grassed-down hops. The major part of our outside experimental work is, however, carried out on the Bodiam Farms of Messrs. Arthur Guinness Son & Co., Ltd., who have at all times been particularly helpful in providing not only land for experiments, but, and even more important, labour and other facilities for running the experiments and for harvesting the plots.

F. C. Thompson,
Acting Head of Department of Hop Research.

View of Experimental Drying Kilns in Hop Laboratory

[*face p. 13*]

REPORT ON CURRENT RESEARCH INTO HOP DRYING

G. A. Watson

This year's Report presents a convenient opportunity to review the Department's programme of Hop Drying research during the last three years.

Due to delay in the completion of the six experimental kilns only a limited amount of work could be carried out during the 1951 drying season, and the only experiments made involved a comparison of the use of sulphur and sulphur dioxide for the bleaching of the hop. Modification of the thermostats on the kilns was carried out during 1952, and a full programme of experimental work was made possible during that year's drying season. During 1953, dial thermometers were fitted to the kilns, as shown in the photograph, reducing considerably the time spent in temperature recording and so enabling a more extensive programme of experiments to be completed. Before discussing the results of this work a survey of the drying problems facing the grower will form a useful introduction and enable the experiments described below to be seen in their correct perspective.

Without a doubt the biggest problem facing the grower to-day is the drying of machine-picked hops; as the use of machines extends an appreciation of the complications present in the drying of these hops is essential. The work of Dr. Burgess has shown the conditions required for the successful drying of hand-picked hops. However, the following points are becoming evident as ones requiring special attention and ones which may involve the reconsideration of some of our ideas with respect to hop-drying.

Machine-picked hops contain an appreciably larger proportion of broken hops and separated "petal" than do normal hand-picked hops. We know that the presence of this broken fraction complicates the task of the dryer when assessing the time at which his hops should come off, but in addition to this problem there are several important questions that must be answered, namely:

(1) How does the presence of this broken fraction affect the time of drying and are quality and valuation likely to be affected by variation in that time?

(2) Is the brewing quality of the hop affected by the severe over-drying that the broken hop receives, bearing in mind that it is the bract or "petal" which carries the hop resins and which is most liable to such over-drying?

(3) Is the re-distribution of moisture within a load of hops, when placed on the cooling floor, affected by the closer packing of the broken fraction, which will tend to prevent movement of air within the heap of hops?

(4) If we find that the presence of the broken fraction does adversely affect the quality of our final sample, can we modify conditions of drying to minimize such effects?

In addition to these problems posed specifically by machine-picked hops, others being investigated are the comparative effects of sulphur and sulphur dioxide on the bleaching of the hops, and in association with N.A.A.S. and N.I.A.E., the design of a flow-meter for measuring air velocities through the load of hops and the collection of data for assessing performance requirements for fans used in hop drying.

These then are our problems and the Department is studying them in a series of four main experiments, they are:

1. A Study of the Fundamental Aspects of Drying of the Hop Cone

In this experiment the rates of drying of the separated strig and bract have been determined and compared with the rate of drying of the whole hop. In brief, single-layer samples of whole hop, separated bract and separated strig, were dried under identical conditions at a constant temperature of 150° F. on a miniature kiln until the whole hop was judged to be dry. At hourly intervals during the drying period small samples were taken and their moisture contents were determined. At each time of sampling a sample of whole hop was taken and dissected into its constituent strigs and bracts and the moisture content of the separated portions determined.

The picture that emerged is given in Fig. 1 which shows the drying of Fuggle hops. From this diagram we can see that very large differences in drying rates exist within the hop cone itself. The whole hop dries steadily from a moisture content of 78 per cent. to one of 7·5 per cent. in just under four hours, while the strig within that hop will dry slowly at first, the rate of drying increasing during the drying process to reach 15 per cent. moisture content in the same time. On the other hand the bract on the whole hop dries rapidly at first, down to a level of about 10 per cent. moisture content in two hours, after

which it dries more slowly to reach a final figure of 4·5 per cent. moisture. Separated bracts are seen to dry even more rapidly, down to 11 per cent. moisture content in one hour, to reach a final level of 3 per cent., while the separated strig is seen to dry rather more

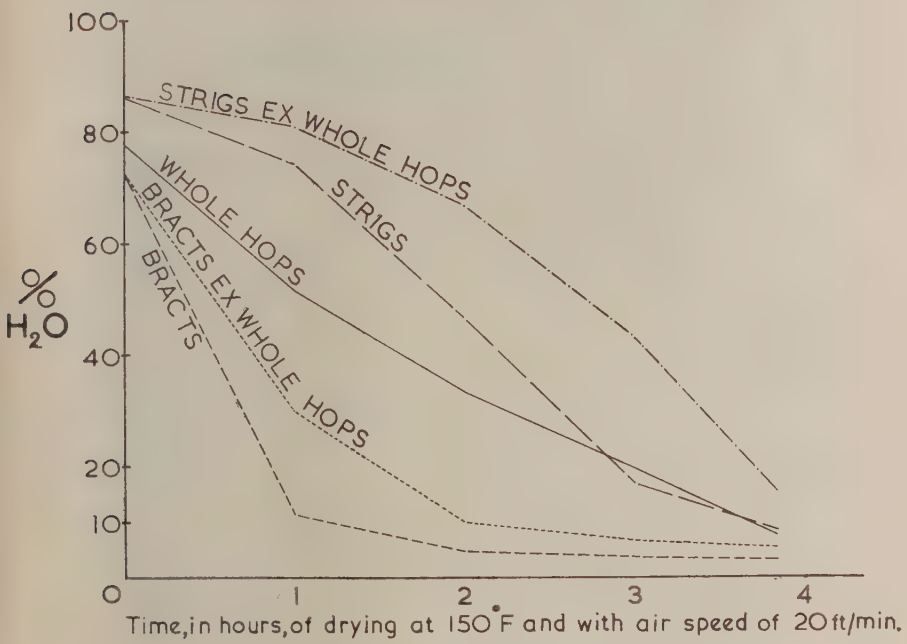

FIG. 1

Drying of Fuggle hop and its separated strig and bract.

rapidly than the whole hop, after a slow start, to reach 8·5 per cent. in 4 hours.

Although this experiment was carried out on a single layer of Fuggle hops, we can infer several points for application to a normal commercial load. They are, firstly, that in a load of completely whole hops, if all the hops were dried to the same condition there would be a difference in moisture content between the strigs and bracts of these hops of approximately 10 per cent. at the end of drying. As hops are taken off at a point when the top layer is slightly under-dried and the bottom layers are slightly over-dried it is likely

that greater moisture content variations than this will exist. Secondly that in a load of whole hops the bracts on those hops will have been at a moisture content of less than 10 per cent. for several hours before the load is taken off, and thirdly, that in a load of machine-picked hops all the above effects will be magnified according to the proportion of broken hops present.

One difficulty the dryer of machine-picked hops must face is now apparent—i.e. where formerly, with hand-picked hops, the handful of hops on which he judged his drying contained very little but whole hops, he must now judge on a handful of hops and separated bracts with the aforementioned increased range of moisture contents. He is faced with the problem of whether he should keep his load drying until he judges the whole hops to be fully dry or take them off when he judges the average moisture content to be satisfactory. An extension of the above experiment in which the reabsorption of water by the hop cone and its various portions was studied, indicates that it is easier for an over-dried hop or its separated fractions to reabsorb moisture than it is for an underdried hop to give up moisture. In consequence, given good cooling floor conditions, it will in general be safer to over-dry slightly than risk having a large proportion of underdried whole hops. The point mentioned previously, that a large proportion of broken hops will tend to prevent redistribution of moisture within the heap of hops on the cooling floor, suggests that if possible the hops should be spread out rather more than is usual to allow for reabsorption of moisture. Alternatively, if cold air were blown for a short time through the hops while still on the kiln, after slight overdrying, the hops might be "brought back" successfully to the desired conditions of "silkiness".

2. Relative Humidity and Temperature Measure in the Exhaust Air from a Kiln

The hop fraction drying experiment has some interesting bearings on another experiment that has been carried out. In an effort to determine whether an instrument may be of value in the assessment of the end of drying, temperature and relative humidity measurements have been taken in the exhaust air above a load of hops. Formalized diagrams drawn from some typical results obtained are given in Figs. 2*a* and 2*b*. These two diagrams show the humidity conditions of the air above a load of hops 16-18 in. deep during (*a*) normal drying conditions, and (*b*) rapid drying conditions.

In Fig. 2*a* (obtained using air speeds of around 20 ft./min., and conventional temperatures starting at 100° F. and rising to 150° F.)

it is seen that the relative humidity curve consists of two sections; a steady maximum at around 90 per cent. relative humidity lasting for several hours, and a second section in which the relative humidity at first falls very sharply and then evens out to a steady minimum at the end of drying. The reason for this definite division into two sections becomes apparent on taking a second look at the first hop fraction drying experiment described. The hop bracts, carrying 75 per cent. of the total moisture within the hop cone, were shown to dry

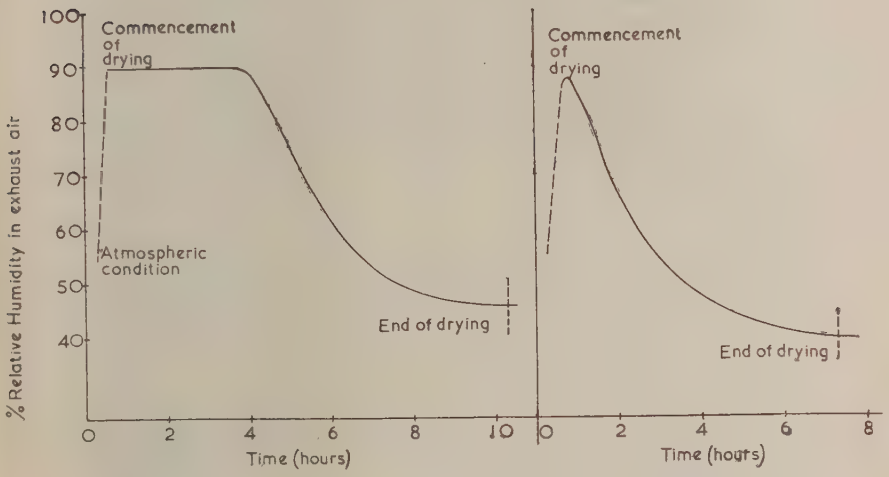

FIG. 2a
Normal Drying

FIG. 2b
Rapid Drying

from 73 per cent. moisture down to 10 per cent. moisture content in some two hours, while the strig, proctected by the enveloping bracts, took over twice as long to reach the same level of moisture content. It is obvious that the first steady maximum must correspond to the rapid evaporation of moisture from the bracts and that the second section relates to the slower process of evaporating moisture from the strigs.

In Fig. 2*b* the division of the relative humidity curve into two sections has been eliminated by using high air speeds of around 50-60 ft./min. and initial temperatures of about 130° F. rising to a maximum of 150° F. It is seen that the relative humidity of the exhaust air begins to fall right from the commencement of drying, again

reaching a steady minimum. In this rapid drying process two points are apparent: first that the danger of reeking has been greatly decreased for there is no water-saturated air above the hops as is the case with the drying represented by Fig. 2*a*, and second that a considerable saving of drying time has been achieved. This saving can be considered as being achieved in two steps; by the rapid mass-evaporation of water from the bracts, eliminating the peak of saturation shown in Fig. 2*a*, and by the fact that the drying temperature can as a result be more rapidly raised to its maximum of 150° F. This last factor will considerably speed up the drying of the strig, for while it is doubtful if increase in air-speed above 25-30 ft./min. results in any appreciable acceleration of its rate of drying, an earlier increase in temperature will have a considerable effect upon this rate.

It has been said that in both Figs. 2*a* and 2*b* the relative humidity of the exhaust air has reached a steady minimum at the end of drying. Under the conditions used in the experiments, in which exhaust air was drawn via wide-bore hosing through a chamber containing the hygrometer, the actual minimum obtained varied between 35 per cent. and 50 per cent. relative humidity depending on the depth of load, air speeds and temperatures used in the various drying runs. With each set of conditions the minimum was easily observed and coincided well with the end of drying as determined by hand. This fact gives hope that instruments may eventually find a place in assessing the end of drying.

The hygrometer is not an ideal instrument for the purpose however. It is slow to respond to changes in moisture content, inaccurate at the extremes of its humidity range and requires protection from condensation and harmful fumes, and in addition is not recommended for use at temperatures around 150° F. For these reasons an alternative instrument is desirable, and it is probable that a thermometer measuring the temperature of the exhaust air will provide a more reliable guide to the condition of the load.

When a stream of warm air passes through a bed of drying material heat is transferred from the air to the material and moisture is evaporated from that material and carried away by the air stream. This transfer of heat will be reflected by a fall in temperature of the inlet air. Thus in Fig. 2*a* the temperature of the exhaust air would remain steady during the period taken up by the steady maximum of relative humidity and would commence to rise only when the relative humidity began to fall. It would continue to rise steadily until, if the hops were to become completely moisture free, the temperature of the exhaust air would be identical with that of the inlet air from

the heater, assuming losses due to radiation, etc., to be negligible. As conditions approaching an equilibrium between the hops and the drying air are reached at about 5-7 per cent. moisture content, in hop drying this condition of temperature equality will not be reached and the exhaust air will reach a steady maximum several degrees below that of the inlet air, depending again upon the particular conditions of loading, air speed, etc.

Thermometers are more accurate than hygrometers, are easy to instal and maintain, require little protection and can be conveniently made to record at a distance. Fitted just above the hop load they may well prove a most valuable aid to the hop dryer, particularly with machine-picked hops, as the instrument can be designed to respond to conditions affected by the entire hop load, and so avoid judging the state of drying on a haphazardly picked handful of hops. It is hoped to extend the investigations on this particular experiment during the coming season.

3. Rapid Drying of Hops

The first two studies described are clarifying our knowledge of the actual drying processes occuring within a load of hops, but they can only give indirect information on some of the problems metioned in the introduction. One of the most important of these problems is that of the overdrying of the bract. This overdrying has always been present, of course, in hand-picked hops, but the position is now aggravated with machine-picked hops in which large separated bract fractions may be present. As the bract carries the hop resins it is important to decide whether this overdrying, amounting to perhaps two-thirds of the total drying time for the bottom layers in a hop load, has any appreciable effect upon the market evaluation and brewing quality of the hop.

Experiments investigating this problem were commenced in 1953. It was decided that the most direct method of study was to dry hops under such conditions of loading, air speed and temperature that samples with widely differing times of drying could be obtained.

It has already been stated that considerable decreases in the time of drying can be obtained by the use of high air speeds and high initial temperature. Under normal conditions of drying, the recommended maximum depth of loading is 0·8 in. of hops for every foot per minute of air speed passing through the hop load. To obtain the drying times demanded of this experiment the kilns needed to be underloaded by comparison with this figure and loads of approximately 18 in. were used irrespective of the air-speed used. To make

the most economical use of the high air speeds tested, speeds of 50-60 ft./min. were only used during the first three hours of a drying run; at the end of this period when the rapid evaporation of the main bulk of moisture was finished, the air speeds were decreased to 30 ft./min. and held there for the remainder of the run. Temperatures used were as given in Table 1.

Table 1

Drying of Early Bird Hops using High Air-speeds and High Initial Temperature.

Series and sample No.	Air speed (ft./min.)		Temperature °F.		Time of drying
	Initial	Final	Initial	Final	
Series 1 No. 1	30	30	160	160	8 h. 15 m.
2	30	30	150	150	9 h. 15 m.
3	30	30	140	140	11 h.
4	30	30	130	140	12 h.
5	30	30	120	140	12 h.
Series 2 No. 1	50	30	160	160	6 h. 5 m.
2	50	30	150	150	7 h. 50 m.
3	50	30	140	140	9 h. 25 m.
4	50	30	130	140	10 h. 5 m.
5	50	30	120	140	10 h. 5 m.
Series No. 1	63	30	160	160	4 h. 40 m.
2	60	30	150	150	9 h. 15 m.
3	65	30	140	140	5 h. 35 m.
4	63	30	130	140	9 h. 16 m.
5	60	30	120	140	9 h. 16 m.

From the figures in Table 1, it can be seen that the drying times obtained varied considerably. A limited amount of water condensation on the upper layers of the hops was observed in Series 1, but no condensation whatsoever was observed in Series 2 and 3. Box samples for market evaluation and pocket samples for brewing trials were prepared.

The results of the market evaluation, to be published in due course, show that no appreciable variation existed between any of the samples obtained, either within any particular series or between the three series. It seems that the market value of the individual samples has not been prejudiced by the wide range of drying times achieved in this experiment. It should be remembered, of course, that this result was obtained under ideal conditions of air-speed and

temperature control, and cooling conditions, and must be confirmed in the forthcoming season before a general recommendation for the use of the quoted high air-speeds and temperatures can be issued. Brewing trials on the samples from this experiment are to be carried out and the results should be of great interest.

We have mentioned previously the advantages of driving off the bract moisture as rapidly as possible. In carrying this out conditions must not be such that the actual temperature of the hop cone rises appreciably while it still contains the bulk of its moisture, as a "dull" sample will result. The temperature of a correctly-dried hop will only commence to rise after the bulk of its moisture has been evaporated. These conditions seem to have been obtained in the experiment described above.

An extension of this experiment was carried out in which similar loads of machine-picked and hand-picked Fuggle hops from the same gardens were dried under conditions of normal and high air-speeds. Again variations in the times of drying were obtained and market valuation of the samples was clearly in favour of the samples dried at high air-speeds. Brewing trials are also being carried out, and as these hops contained a large broken hop fraction the results should be of great value when studied together with the results from the other experiments.

4. The Use of Sulphur and Sulphur Dioxide

The work of Dr. Burgess has established the conditions required for the satisfactory use of sulphur in hop drying. However, post-war interest within the industry on the economical use of sulphur and the world sulphur shortage of 1950-51 prompted the Department to commence a new series of experiments in 1951.

In the years 1951, 1952 and 1953 a variety of experiments have been carried out. Sulphured hops have been compared with unsulphured hops; the use of burning sulphur has been compared against that of sulphur dioxide obtained from cylinders of liquid sulphur dioxide; investigations into the optimum amounts of sulphur or sulphur dioxide required and their time of contact with the hops have also been made. From all these trials samples for market evaluation and brewing trials were prepared and it is hoped to publish some of the results obtained shortly. In general, the results show that hops can receive the same valuation whether they are sulphured by using burning sulphur or by using gaseous sulphur dioxide, and that the use of sulphur in either form tends to depress the bittering power of the hop.

Among points that are receiving increasing study are the possibility of using sulphur dioxide in a slow air stream passed through the hops for the minimum time of contact period before the actual drying process begins, in which high air-speed drying methods may be used; the use of a pre-sulphuring chamber before the hops are placed on the kiln; and the surmounting of the practical difficulties of conveniently passing gaseous sulphur dioxide through the hop load.

Conclusion

In the foregoing account an attempt has been made to describe in general outline the main programme of experimental work on hop-drying carried out over the last three years in the Department. Much of this work was prompted by interest from within the industry; growers are becoming increasingly aware that their drying methods can be considerably improved and this opinion is confirmed on reference to the latest work carried out overseas, particularly in America. While it is appreciated that full consideration must be given to the capital expenditure involved, it is our hope that, working in collaboration with the N.A.A.S., some of the possibilities mentioned above may prove to be of commercial application.

HEIGHT OF WIREWORK AND SPACING TRIAL

PROGRESS REPORT I

F. H. Beard and F. C. Thompson

The object of this trial is to ascertain the combination of height and spacing which will produce the type of growth most suitable for machine picking while at the same time giving satisfactory crop yield. Some preliminary studies on the effect of varying the width of planting on the Butcher system of wirework were made by Beard (1937) at East Malling, and the present experiment was initiated by Dr. Burgess at Wye, prior to his retirement from the position of Head of the Department, and was planted-up in 1951 on land previously occupied by Goldings. After grubbing the Goldings, the ground was subsoiled to a depth of 13½ in. and sown with a short term ley in the spring of 1950. In the autumn of that year, the land was cross-ploughed and subsoiled again.

There are three heights of wirework, 13 ft., 15 ft. and 17 ft. 3 in., combined with three spacings in one direction of 6 ft., 7 ft. 6 in. and 9 ft. The cross spacing is uniform at 6 ft. 6 in. to facilitate cross cultivation. This means that considered as a square plant, the spacings are approximately 6 ft., 7 ft. and 7½ ft. square, respectively. There are two replications of each combination of height and spacing and the treatments continue across four varieties of hops; of these the varieties *Fuggle* and *John Ford* were planted as layer cuttings in 1951, while the varieties *Bullion* and *Brewer's Gold* were planted as bedded-sets at the same time.

The plants of Bullion and Brewer's Gold were sufficiently well established for crop records to be taken in 1952, and the results are given in Table 1. Though the yield was actually measured in terms of green hops, the figures are stated in cwt. of dry hops, since this is the commonly accepted method of expressing hop yield.

1952 Results

It will be seen that the highest yield per acre of Bullion was produced on the 15 ft. wirework with the plants spaced $6 \times 6\frac{1}{2}$ ft.; the highest yield of Brewer's Gold was also produced on the 15 ft. wirework, but the spacing in this case was $7\frac{1}{2} \times 6\frac{1}{2}$ ft. The yield per hill is

not given, but it was found that the wider the spacing, the greater was the yield per hill; this did not compensate, however, for the fewer hills per acre in the widest planted hops.

TABLE 1

WEIGHT OF HOPS PICKED IN 1952 IN CWT/ACRE DRY HOPS.*

Variety	Spacing	Hills per acre	Heights			Mean yield (spacings)
			17¼ ft.	15 ft.	13 ft.	
Bullion ..	9 × 6½ ft.	745	24·50	30·00	25·50	26·75
	7½ × 6½ ft.	893	29·50	31·25	25·00	28·75
	6 × 6½ ft.	1,117	31·25	35·50	31·25	32·75
Mean yield (heights) ..			28·50	32·25	27·75	
Brewer's Gold ..	9 × 6½ ft.	745	27·50	26·50	28·75	27·50
	7½ × 6½ ft.	893	27·75	32·75	29·75	30·00
	6 × 6½ ft.	1,117	30·50	30·50	29·75	30·25
Mean yield (heights) ..			28·50	30·00	29·50	

* Estimated on the basis of 4 lb. green hops = 1 lb. dry hops.

1953 RESULTS

By 1953 all four varieties of hops in the experiment were sufficiently well established for crop yields to be taken and detailed records of growth made.

Table 2 is a summary table of the yields per hill in terms of bushels. While these figures are of interest in showing the marked increase in yield per hill with the wider spacing, it is *yield per acre* which is the final measure of the success of the treatment. These data are shown in Table 3 which gives the yield in cwt. per acre for all combinations of treatments tested.

Comparing the yield per acre data in Tables 1 and 3, it will be seen that with Bullion the influence of both height and spacing has not produced such marked differences in 1953 as in 1952, the inference being that the root range of the plants is becoming more extensive, and aerial growth more vigorous, with the wider spacings, and compensating for the smaller number of hills per acre. With Brewer's Gold this effect has not taken place, but this may be due to the rather uneven growth made by this variety in 1953 and to the adverse

TABLE 2
YIELD DATA IN BUSHELS PER HILL.*

Variety	Height			Spacing		
	17½ ft.	15 ft.	13 ft.	9 ft.	7½ ft.	6 ft.
Fuggle ..	2·49	2·55	2·30	2·72	2·47	2·14
John Ford	2·60	2·85	2·57	2·98	2·75	2·30
Bullion ..	3·07	3·07	2·88	3·89	3·04	2·48
Brewer's Gold ..	2·33	2·48	2·43	2·72	2·53	1·99

* Estimated on the basis of 5 lb. green hops = 1 bushel.

TABLE 3
WEIGHT OF HOPS PICKED IN 1953 IN CWT/ACRE DRY HOPS.*

Variety	Spacing	Hills per acre	Heights			Mean yield (Different spacings)
			17½ ft.	15 ft.	13 ft.	
Fuggle "N"	9 × 6½ ft.	745	22·92	23·90	21·08	22·63
	7½ × 6½ ft.	893	24·91	25·08	23·90	24·63
	6 × 6½ ft.	1,117	27·46	27·99	24·45	26·63
Mean yield (heights)			25·10	25·66	23·14	
John Ford ..	9 × 6½ ft.	745	25·17	25·97	23·09	24·74
	7½ × 6½ ft.	893	25·61	29·99	26·99	27·33
	6 × 6½ ft.	1,117	27·18	30·21	28·65	28·68
Mean yield (heights)			25·99	28·72	26·04	
Bullion ..	9 × 6½ ft.	745	29·14	30·61	27·71	29·15
	7½ × 6½ ft.	893	29·06	31·48	30·32	30·29
	6 × 6½ ft.	1,117	34·63	29·60	28·41	30·88
Mean yield (heights)			30·94	30·56	28·81	
Brewer's Gold ..	9 × 6½ ft.	745	21·74	24·14	21·85	22·58
	7½ × 6½ ft.	893	25·57	25·56	25·88	25·57
	6 × 6½ ft.	1,117	23·92	23·94	26·02	24·63
Mean yield (heights)			23·74	24·55	24·48	

* Estimated on the basis of 4 lb. green hops = 1 lb. dry hops.

Statistical Analysis. Fuggle: Highly significant effect due to spacings.
John Ford: Significant effect due to spacing.
Bullion: No significant effects.
Brewer's Gold: No significant effects

conditions at picking time when, in particular, the plants on the highest wirework were badly knocked about by gales and a smaller crop harvested in consequence. Bullion, being an earlier hop, was harvested before the gales occurred in 1953.

Records of growth were first taken at the end of June when no appreciable differences were noted between the different treatments. The next recording was at the beginning of August, when it was observed that with Bullion and Brewer's Gold there was a definite tendency for hops to develop lower down the bine with the wider spacing, and to a lesser extent with the higher wirework. John Ford showed the same trend, whereas Fuggle, in contrast, showed a tendency for the lower laterals to be barren of hops at all heights and spacings. A final record was made in early September and the conclusions reached, considered in relation to the yield data set out in Table 3, are given below:

Fuggle

For crop production 15 ft. height and $7\frac{1}{2} \times 6\frac{1}{2}$ ft. spacing was considered the best. For machine picking the same spacing but the highest wirework ($17\frac{1}{4}$ ft.) was recorded as most suitable.

When the crop per acre is considered, however, it will be seen that the 6 ft. spacing has the highest yield, although the type of growth developed was considered to be too housed-in for a full crop. This emphasizes the point that in assessing growth by visual observation, it is very difficult to give full weight to the number of hills per acre in putting a figure on crop yield.

John Ford

As with the Fuggle variety, 15 ft. height and $7\frac{1}{2} \times 6\frac{1}{2}$ ft. spacing was recorded as best for crop production, the 6 ft. spacing being regarded as too housed-in. For machine picking the highest wirework and wider spacings appeared to be giving the most suitable growth. The highest yield, however, again as with Fuggle, is found with the 6 ft. spacing.

Bullion

With this variety it was considered that spacing was the dominant factor, the growth at $9 \times 6\frac{1}{2}$ ft. being recorded as good at all heights, with a preference for $17\frac{1}{4}$ ft. wirework for machine picking. This dominant influence of spacing is borne out by the yield data in

Table 3; the influence of height of wirework on yield, however, is more pronounced than appeared from visual observation.

Brewer's Gold

With this variety it was decided that the 17¼ ft. height and the wider spacings had given the best growth with a preference for the 9 ft. spacing for machine picking.

Yield data favours the medium 7½ ft. spacing at all heights.

Discussion and Conclusions

There is no doubt that both high wirework and wide spacing encourage the development of the type of growth which is generally agreed to be most suitable for machine picking—i.e. with the hops well distributed along the bine and an absence of large, tangled heads. Of these two factors, it was recorded that height of wirework was the dominant influence in 1953, with all four varieties tested.

On the other hand, the influence of different spacings on yield per acre was much more pronounced than that due to different heights of wirework. This, as would appear obvious, is due to the reduction in number of hills per acre as the distance apart is increased, but what is not so obvious is the magnitude of this effect. Thus it was generally agreed by experienced observers, that the growth made by all varieties on the $6 \times 6\frac{1}{2}$ ft. planting, was inferior to that on the wider spacings and it was forecast that the yield would be below that found on the medium spacing of $7\frac{1}{2} \times 6\frac{1}{2}$ ft. With Fuggle and John Ford this did not prove to be so, and with the stronger growing Bullion and Brewer's Gold, there was little difference in mean yield per acre between the two spacings. As stated earlier, this illustrates how the natural tendency of an observer is to assess crop yield on the performance of individual hills and to overlook the influence of the number of hills per acre. The wider spacings should, however, lower costs of production, by speeding up the operations of dressing, pulling and training, and result in an appreciably smaller quantity of string being used. The advantages of allowing more light and air to the plants should also show up in improved hop quality and greater ease in disease control.

Until the plants have had time to develop an extensive root range the full benefits of wide spacing are not likely to be apparent, and an experiment of this type must be continued for a number of years before definite conclusions can be drawn. Nevertheless, the results obtained in 1953 have shown that increasing the height of

wirework has produced the type of growth desired for machine picking, without having the marked effect on crop yield shown by varying the width of spacing.

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THE NEW VARIETIES OF HOPS

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(The authors acknowledge the kindness of the Editor of the *Brewers' Guild Journal* for permission to make free use of a paper by C. L. Jary, read before the London Section of the Incorporated Brewers' Guild and published in the *Brewer's Guild Journal*, May, 1954.)

With all crops new varieties are continually being introduced and where they prove superior to those in cultivation the latter are gradually displaced. This trend can be observed in the case of hops, though it has proceeded more slowly than with many other crops for reasons discussed later. Hops were first cultivated in this country in the sixteenth century, but those varieties considered to be "established" to-day were not introduced until the latter part of the nineteenth century. Others, such as Tolhurst, Bates Brewer and Prolifics, introduced at about the same time failed to establish themselves in favour and have passed gradually out of cultivation in relatively recent times. All these varieties arose as chance seedlings or variations of existing types and were selected and propagated by progressive growers. It was not until Professor Salmon started his work in the early part of this century that any serious attempt was made to *breed* new varieties. Whilst there will always be enterprising growers anxious to try out something new, it must not be forgotten that the real reason for growing hops is to make a profit and that each grower will tend to restrict himself to those varieties which under his particular conditions produce the greatest profit. This is the theoretical position, but it is never completely reached. Adjustment is slow, partly because the hop is a long-lived plant and new gardens expensive to establish, but mainly because of the time taken for a new variety to become generally accepted and to command a satisfactory and reliable valuation. This obviously implies a consistent demand from the brewers, and it is also important that this should be fairly general, rather than peculiar to a few brewers.

New varieties which are likely to succeed must, therefore, be

able to fill some particular need of the industry and in order to do this they must possess such combinations of desirable qualities as are lacking in established varieties. Considered in this light, the existing New Varieties may conveniently be considered under four headings, although there is some overlapping of varieties between them.

Substitutes for American Hops.
Wilt-tolerant Varieties.
Higher Valuation Hops to replace Fuggle.
Hops for Machine Picking.

There is room for a fifth category, namely, resistance to disease other than Progressive *Verticillium* Wilt, and in particular to Downy Mildew. At the moment there is no commercial variety exhibiting really effective resistance to this disease. Resistance to Mould (Powdery Mildew) is also desirable, but actual immunity has already been achieved in a few seedlings.

These categories will now be discussed separately in more detail.

Substitutes for American Hops

At an early stage in his breeding work Professor Salmon's interest was aroused by the insistence of certain brewers that they must use a proportion of American hops. He, therefore, endeavoured to introduce the essential qualities of American hops by using Wild Canadian and New-Mexican male hops for crossing with English hops. There can be no doubt that he was supremely successful in this work. He produced seedlings of heavy cropping capacity with preservative values higher than the American hops themselves, which induced American hop-growers to import sets of some of them. These hops also possessed aromas of the American type and as far as the home market was concerned, this came to be regarded more often than not as a disadvantage. Nevertheless, two of his earliest varieties, Brewer's Gold and Bullion, have become widely accepted as substitutes for American hops. Their potential acreage will necessarily always be limited by the proportion of that type of hop which the brewers require, though this demand itself may not necessarily be static.

Wilt-Tolerant Varieties

The most urgent and widespread need of growers to-day is for varieties which will not succumb to Progressive *Verticillium* Wilt, the disease which has caused havoc among established varieties,

notably Fuggle, in mid-Kent and the Weald. Nearly 200 farms are now infected representing more than a quarter of all the hop farms in South-Eastern England, and about a fifth of the hop farms in the country as a whole. An assessment of the area of actual land infected is more difficult, but it is probably close on 3,000 acres, which represents approximately one seventh of the total hop acreage.

Since 1948, the wilt-tolerant variety Keyworth's Midseason (OR55) has been planted on infected land, and a seond variety, Keyworth's Early (OJ47) followed a few years later. OR55 was at first planted as fast as it could be propagated, but as it has proved to be not generally acceptable to the brewers, any further extension of acreage has been discouraged for the past two years. OJ47 was never popular, either with growers or brewers, and bad attacks of mould in the last two years have hastened its decline. At present there are rather more than 500 acres of OR55 and less than 100 acres of OJ47. While, therefore, these varieties undoubtedly saved the situation for some growers for the time being, they are not, and cannot be, the final answer to wilt. Probably another 1,000 acres of infected gardens would be grubbed and replanted almost immediately with acceptable wilt-tolerant varieties if they were available, but ultimately not only would all the land at present infected be replanted, but also all hop land in the main area where the disease occurs, and this covers the most concentrated hop area in the country. The potential demand is, therefore, a very big one and may well amount to one fifth of the total acreage.

Unfortunately the varieties which will ultimately meet this need are not yet available, but in the meantime two "stop-gap" varieties are being offered as partial substitutes, though not yet in quantities sufficient to make any real impression on the problem, and even they are known to have certain faults. These varieties are Bramling Cross (OT48) and Messrs. Whitbread's Seedling "1147", and, like the Keyworth varieties, their wilt-tolerance was a happy chance and not the result of deliberate breeding. Bramling Cross was the first of these to be made available. It was raised as early as 1927, but did not at first attract attention. For the past few years, however, it has been distributed from Wye in lots of 25 sets. This procedure has meant that recipients have had to build up their own stocks and consequently only a few pockets have hitherto been produced. More recently it has been supplied to specialist propagators and will, therefore, soon be available in commercial quantities. In 1952 "1147" attracted attention at the Annual Hop Walk of the Association of Growers of New Varieties of Hops, and trials were

hastily arranged. It was potentially available in larger quantities than OT48, but for the fact that being on a wilt-infected farm, its distribution was prohibited under the Progressive *Verticillium* Wilt of Hops Order, except under licence. In view of the difficult situation the Ministry of Agriculture granted a licence, and this variety is now being distributed for planting on wilt-infected land only on an allocation system organized by the Hops Marketing Board. This is recognized to be an interim emergency measure since it is one fundamentally disapproved of by the plant pathologists, and in the meantime East Malling Research Station has undertaken to produce a wilt-free strain of this variety which will then be available for intensive propagation on clean land.

The fact that perfect wilt tolerant hops are not yet available does not mean that nothing has been done about the problem. The deliberate breeding of such varieties has been in progress for several years at Wye and East Malling Research Station, a first stage having been production of wilt-tolerant males, so that this quality could be introduced from both parents. Of the East Malling Seedlings which were raised in 1946, three, C2, D1 and D3 have reached the third year of farm trials, and have recently received favourable reports in a large-scale brewing test. A fourth seedling, J2 is one year behind them, but preliminary brewing reports are also favourable. These varieties are likely to be available in fair quantities for planting by 1959 or 1960, provided that East Malling Research Station decides to release them on the results of combined trials. In 1950, East Malling Research Station and Wye collaborated in the start of a large-scale project. Controlled crosses were made at East Malling Research Station and from these, 3,000 seedlings were raised at Wye and layered. In the following year the bedded sets were sent to East Malling for wilt testing, and the layered cuttings grown on at Wye. By this means, the seedlings were reduced to 170 after two years. A high proportion of the seedlings were wilt-tolerant, but many were discarded on other grounds, and in the process of selection particular attention has been paid to good aroma. This work will have to proceed for a few years more to reduce these 170 seedlings still further, leaving a manageable number for large-scale growing and brewing trials. After they have been thoroughly proved, intensive propagation must take place before the results of the work will be brought to final fruition in the form of those large quantities of sets which will be needed to plant up a substantial acreage of wilt-infected land. The arrangements for the building up of nuclear stocks of these and other desirable new varieties for issue to specialist propagators and thence

to commercial growers as really healthy planting material which is true to type, are under consideration by the Ministry of Agriculture and Fisheries in consultation with East Malling and Wye. At the same time, Wye has undertaken to propagate a series of wilt-tolerant males (originally selected and tested at East Malling Research Station) for planting with them.

Higher Valuation Hops to Replace Fuggle

The fact that at the present time Fuggle occupies about 75 per cent. of the hop acreage is an indication that it does to a large extent meet the needs of both growers and brewers. The ravages of wilt discussed above have already compelled its partial replacement in certain areas by wilt-tolerant varieties, but apart altogether from wilt, growers would obviously be interested in a hop which would command a higher valuation, but do equally well under Fuggle conditions. The Goldings will not tolerate the heavy, often shallow soils with impeded drainage on which many Fuggle hops are grown. To some extent, the "Golding Varieties" and even Bramling form an intermediate category, but there remain large areas, notably in the Weald of Kent and Sussex, where Fuggle is the only one of the older varieties which can be expected to succeed. A further point is that Fuggle is a mosaic-tolerant hop, whereas the Goldings and "Golding Varieties" are sensitive to mosaic and may become infected from neighbouring Fuggles in which its presence goes undetected. It is thus technically undesirable that these two groups of varieties should be grown side by side. Several of the New Varieties are able to meet this requirement as far as growing conditions and mosaic-tolerance are concerned, and their relatively high resin contents especially when associated with a good English aroma make them potentially valuable hops. This is, in fact, becoming recognized by the increasing tendency towards higher ranges of valuation. The sorting out of the many possible varieties will be entirely dependent upon the reactions of the brewers, and the adjustment and finally stabilization of their valuation position.

The varieties in this category which are most likely to have a future are the group of seedlings with a Golding parentage on the female side to which the high P.V. potential has been added through the male, thus combining a Golding type of aroma with high preservative value. The best known is *Northern Brewer* whose rapid rise to popularity both at home and overseas in the last few years has been quite phenomenal.

Hops for Machine Picking

The recent extension of machine picking has, as it were, "created" a new fault in Fuggle—it is not a good machine picker. Admittedly it picks fairly well in the middle of the season and something could be done by selection within the range of Fuggle types to obtain a series of strains ripening in succession. The fact remains, however, that most of the New Varieties with their inherently greater toughness are still superior for machine picking and already provide a succession of ripening periods. Attempts are being made at Wye to produce triploid hops, which being virtually seedless will be even less liable to shatter.

Resistance to Other Diseases

Unfortunately, all the New Varieties discussed above have certain defects, the outstanding one from the growers' point of view being susceptibility to Downy Mildew, in which respect they are more comparable with the Goldings than the Fuggle. Whilst this disease can be commercially controlled by spiking, spraying and the replacement of hills which are killed, all these measures involve considerable expense and worry. Immunity to mould has already been achieved in certain seedlings, notably Sunshine (V94), but the defeat of "Downy" is likely to be more protracted, since the inheritance of the genetical factors involved has not yet been studied in this country and new techniques for the testing of seedlings will have to be evolved.

It will be seen that much remains to be done in the quest for the perfect hop, or rather series of hops, for the lessons of the past in respect of Progressive *Verticillium* Wilt, clearly show the folly of relying too much on one variety. Realization of this principle should encourage an open-minded approach to the whole question of new varieties. No one would wish to force varieties of dubious worth on the Industry, but provision now exists for carrying out research and official testing into both growing and brewing qualities, and the full co-operation of all sections of the Industry and of the Ministry of Agriculture, could result in a more rapid appraisal of the worth of new varieties and their subsequent proper introduction into commerce.

Characteristics of the individual New Varieties

The remainder of this paper discusses the characteristics of the more acceptable or promising of the New Varieties, and mentions briefly those which have failed to establish themselves.

Substitutes for American Hops

There are only two varieties in this group, Brewers' Gold and Bullion. Both are seedlings of a wild hop from Manitoba, Canada, and very similar in general character. They are very heavy croppers (over 25 cwt. per acre) with good bushels/cwt. ratios, very high resins contents (80-100 P.V.) and aromas of the American type. At present top grades are valued slightly above Fuggle.

Brewer's Gold (C9a). Was raised in 1919 and introduced to growers in 1934. It became popular with brewers whilst its high cropping appealed to growers so that the acreage has steadily increased to the present level of rather over 200 acres, the largest acreage of any new variety other than wilt-tolerant Keyworth's Midseason. This acreage is sufficient to meet the present estimated home demand, but an additional 60 acres might be needed to meet the export demand as well, calculated on the basis of an average yield of 25 cwt. per acre. It is also grown in U.S.A. and Canada. Its characters are now fairly well known and are such that modifications of the normal growing technique are necessary if the variety is to be grown satisfactorily. The outstanding feature is the extreme vigour of the laterals, many of which find their way to the strings and become secondary bines often reaching the top wire. For this reason each string should be furnished with only a single bine. Wider spacing and higher wirework than normal are also essential; a 7 feet square plant, and 16 ft. wirework would form a suitable combination under most conditions. If these precautions are not taken a dense tangled mass of bine will result with consequent spraying and picking difficulties. The hills should be pulled as hard as possible consistent with allowing sufficient bine for furnishing the strings. As the hills throw relatively few shoots compared to the older varieties there is a tendency for pulling to be lighter than it should be. The variety has certain faults from the growers' viewpoint. It is probably the most difficult variety for hand picking owing to the twisted bines and laterals and the small fluffy "under-hops", whilst the bine is rough to the pickers hands. It is a true late hop and thus may not be suitable for growers in late districts. In wet situations it is liable to suffer from phytophthora root rot. It receives special valuation (Grade 1. £29 10s.).

Bullion (Q43). Was raised in 1919 and Introduced in 1938. Whilst very similar in general character to Brewer's Gold it is from the growers viewpoint superior to the latter in some respects. It is 10-14 days earlier in season and the cones are bolder and firmer, whilst it is not known to suffer from phytophthora. Formerly it was less in demand by brewers probably owing to its very strong "black

currant" aroma, but this now appears to be considered less of an objection. It is valued only slightly below Brewer's Gold, and the present production does not meet the home demand, so that it may be expected to challenge that variety. In order to supply the present estimated home and export demand, approximately another 70 acres would be needed, allowing the same average crop as Brewer's Gold. It receives special valuation (Grade 1. £29 5s.).

Wilt-Tolerant Varieties

The position of this group is not yet stable, and present and future varieties have inevitably been discussed to some extent in the exposition of the problem. A more detailed account is, however, appropriate here.

Keyworth's Midseason (OR55) (second generation from New Mexican wild hop) is a reasonably good grower's hop on Fuggle land apart from susceptibility of the cones to Downy Mildew and proneness to inter-veinal yellowing of the leaves, whose cause is not fully understood, but may well be associated with shortage of nitrogen.

Keyworth's Early (OJ47) (3rd generation from New Mexican wild hop) has the advantage of being early, but otherwise there is little to be said for it. It never achieved a large acreage and is now being grubbed.

Bramling Cross (OT48) (Bramling by male from Manitoba wild hop) is a satisfactory growers' hop, though liable to be a little short of bine. It is midseason in ripening. There is still some doubt about its brewing value, but this is largely due to the fact that only small quantities have hitherto been available.

"1147" of unknown parentage is a "Golding Variety" type of hop, and is the only existing wilt-tolerant variety with a purely English aroma. Observations on its behaviour have hitherto been limited to one farm, but it appears to be of moderately good cropping capacity, though it is a poor propagator and slow to establish itself. It has received favourable reports in brewing tests.

The other seedlings mentioned earlier are too new for their characteristics to be sufficiently well established.

Higher Valuation Hops to Replace Fuggle

The majority of the new varieties fall into this group, though at the present time only four or five appear to have future prospects. The most promising are two varieties, Northern Brewer and John Ford, raised by crossing Canterbury Golding with a male seedling of Brewer's Gold. They were raised in 1934 and introduced in 1944.

Northern Brewer (WFB135) was the first of the New Varieties to be valued on a Golding basis, and it is estimated that at the present time demand exceeds supply by an amount representing approximately 200 acres. Nearly two-thirds of the total demand is for export. The bine is a characteristic purplish red and the bold cones are densely clustered on laterals of moderate length. The cones have a large number of petals, the bracts being a markedly darker green than the bracteoles. There is an unfortunate tendency for the production of leafy cones. Bine is rather sparse so that hills should be pulled lightly, and as they climb badly the strings should not have too flat a slope. It has a high P.V. of about 90, which deteriorates but slowly in storage. It is an early midseason hop of good average cropping capacity and is definitely susceptible to Downy Mildew, but probably not more so than Goldings. In conclusion it may be said that its faults are more than balanced by the high valuation that a well grown sample obtains.

John Ford (WFA90) is very similar to the above, but is slightly later in season and a rather heavier cropper. It is, however, more susceptible to Downy Mildew (especially in the rootstock) and is particularly prone to lateral and terminal spikes, so that probably most growers will prefer Northern Brewer since the valuation of the two are equal. Present demand also exceeds supply, but not to the same extent as Northern Brewer particularly in respect of export. This, however, may be merely because it is not yet so well known.

Norton Court Golding (WFG19) a sister variety to the two above and strongly resembling them in general character, though it is not quite so vigorous, was introduced to growers as recently as 1952. Thus, there is not yet enough of it in commerce for its performance to be assessed or receive a definite valuation. It seems doubtful if it will seriously compete with Northern Brewer.

Pride of Kent (170a) (a seedling of Brewer's Gold) was raised in 1931 and introduced in 1946. It has been planted up by some growers and at the present time the acreage is about half that of Northern Brewer. It is of moderate vigour, with fine bine which climbs readily. Although it is a late midseason hop, ripening slightly later than Northern Brewer, it is one of the earliest to start growth, and, therefore, may receive harder pulling than it needs. It should be pulled only lightly. The very attractive, pointed, pale cones are borne on long laterals, but these do not become tangled. It is rather less rich than Northern Brewer and John Ford and is at present valued as a "Golding Variety". The existing home demand is met by present production, but there is an export demand representing

roughly a further 30 acres. Though not yet widely grown there is some evidence that it flourishes on heavy land and dislikes the lighter well drained soils. Though not more liable to Downy Mildew attack on bine and cones than most of the New Varieties it is liable to infection of straps and rootstock.

Sunshine (V94) raised in 1927 from a Golding type hop of unknown origin and introduced in 1946, gets its name from the distinctive yellow colouring of the leaves in the early part of the season. This characteristic leaf colour is probably derived on the male side from the ornamental "Golden Hop". Vigour is moderate and the attractive Golding type cones are borne on short laterals. Cropping is moderately good, but its P.V. is lower than Northern Brewer or Pride of Kent, though above that of Goldings. Sunshine is a particularly satisfactory hop from the disease angle being among the most resistant of present varieties to Downy Mildew and immune to Mould. Lack of demand from brewers militates against its great popularity with growers. It receives Fuggle valuation.

Early Choice (FF21) a seedling of Bramling introduced in 1948, appears to have attractions for the grower in that it is an early hop suitable for growing with Fuggle and resembles Sunshine in its degree of resistance to Downy Mildew and Mould. Hitherto it has not been taken up by growers and there is not at present sufficient acreage for its performance and value to be properly assessed. It receives G.V. valuation, but at present, demand from brewers is not encouraging.

Copper Hop (OK40) (fourth generation from Oregon Cluster) has only very recently been named. It is not yet widely grown, but appears to be a midseason hop of moderate cropping capacity, easily grown and showing about the same degree of resistance as Sunshine to Downy Mildew and Mould. It receives G.V. valuation.

Varieties not now in demand

During the past 20 years a number of new varieties, which were tentatively introduced, have failed to establish themselves in favour and are now not grown or only on a very limited scale.

Early Promise (X35) derived from hop of unknown origin introduced in 1937 was for many years popular with growers and acceptible to brewers, and reached a peak of 101 acres—a very substantial acreage for a New Variety. Recently it has been severely down graded in valuation and in consequence is likely to go out of cultivation. The history of this variety illustrates the uncertainty which must always face pioneers of new varieties.

Brewer's Favourite (OP21) introduced in 1934, and *Fillpocket* (Z62) in 1936 both derived from Oregon Cluster, were found to be very liable to rootstock infection from Downy Mildew, which reduced their effective cropping capacity. Brewer's Favourite would have been more appropriately named "Picker's Favourite" as it is the easiest picking hop so far produced. A few Brewer's Favourite are still grown and receive Fuggle valuation, but Fillpocket has now disappeared.

Quality (0063) introduced at the same time as Fillpocket also derived from Oregon Cluster. It is a moderate, but regular, cropper, but is not now liked by brewers. It is still grown on a small scale and receives Fuggle valuation.

Brewer's Stand-by (HH44) introduced in 1943, was a seedling of unknown parentage, but obviously has some Manitoba blood in it. Growth and cropping are poor in cold seasons, cones are borne on long untidy laterals, and are moderately resistant to Downy Mildew infection. A small acreage is still grown and receives G.V. valuation.

Malling Midseason (BB28) derived from the Oregon Cluster and also introduced in 1943, is a steady average cropper with a P.V. about the same as Pride of Kent. Straps and hills are liable to Downy Mildew injury. A small acreage is grown and received "Fuggle plus" valuation. There is a definite demand for this variety, but it is confined to one large brewery.

College Cluster (N15 bis) derived from a New Mexican hop, is a very distinctive variety with relatively short bine growth, but bearing dense masses of cones on short laterals and giving heavy and regular crops. The small acreage grown received Fuggle valuation, but it is not now liked by brewers.

Concord (OH44) a "Golding Variety" type hop derived from the Golden Hop and introduced in 1948 is an easily grown variety, similar to Sunshine in its resistance to Downy Mildew and Mould. It is, however, liable to wilt caused by *Verticillium dahliae* on some sites. The small acreage grown receives G.V. valuation.

Nonsuch (OB53). This variety differs from all the others which have not proved acceptable by its high degree of wilt-tolerance, but its cropping capacity was too low to make it a commercial proposition. It has, however, been used as a parent in breeding work for new tolerant varieties, and its very high P.V. is also an advantage in this respect.

Hops for Machine Picking

All the New Varieties with the exception of College Cluster, whose cones are too big, and whose brittle laterals are easily torn off,

stand up to machine picking better than Fuggle, and indeed produce very satisfactory samples. Clear evidence for this is seen by the fact that the first place in Class A of the 1953 Exhibition of New Varieties of Hops were taken by Northern Brewer, Sunshine and Norton Court Golding picked by machine.

Brewing Demand

In the above discussion of individual varieties, indications have been given of the present position of supply and demand, and the current valuations. It must be realized, however, that these are statements, or in some cases only estimates, of the *present position*, and that it is impossible to make any long-term forecast of the future preferences of the brewing industry.

PLANT BREEDING SECTION

REVIEW OF THE YEAR'S WORK

R. A. Neve and R. F. Farrar with Professor E. S. Salmon

Verticillium Wilt Tolerance

The third season's work on the Wye/East Malling Research Station joint breeding project has been completed. Of the 235 varieties carried on from 1952, 77 were again tested for Wilt tolerance at East Malling, this time on a three-plant basis. Single hills of all 235 varieties were planted at Wye for cultural observation.

Of the 77 varieties represented at East Malling, 48 were discarded as being too susceptible to Wilt, or as having no commercial promise.

Apart from the Wilt aspect, other factors taken into account in making the selections were crop, richness and aroma of the cones, and downy mildew susceptibility.

A total of 170 varieties is now left in the scheme. These varieties were propagated at Wye during 1953 and have provided clonal material for future testing for wilt tolerance at East Malling, and for further propagation to establish clean stocks of each variety at Wye.

The seedling families from the three successful crosses made of Nonsuch (OB53) with *Verticillium* Wilt tolerant males during 1952, were planted out in the nursery garden and the first characteristics have been recorded. One of the crosses produced very little seed, this cross was repeated in 1953, and a good harvest of seed resulted.

Polyploid Hops

Examination of seedlings raised from colchicine treated plants confirmed that the tetraploid material of Brewer's Gold and Bullion had been maintained, and also showed that tetraploid plants of Eastwell Golding had been produced. This known tetraploid material can now be used for raising triploid seedlings from these three varieties. It is unfortunate that no tetraploid Fuggle material has been produced as a result of colchicine treatment, but a fresh attempt will be made in 1954.

The open pollinated triploid families of Brewer's Gold and Bullion were further examined. Although only in their second season, most plants were extremely vigorous and yielded well.

A few plants produced cones very different in character from those of their parent, but in general the similarity between the seedlings and mother variety was most striking. The cones grew out normally, were practically seedless and proved very resistant to shattering.

Box samples prepared from 22 of the more promising triploid seedlings of Bullion and three seedlings of Brewer's Gold, were examined by Col. Richardson. All were described as rich and having a very good side and rub. Aroma ranged from pleasant mild American to unpleasant Manitoba, but it was considered that the majority would be acceptable as substitutes for Brewer's Gold or Bullion with the advantages of being richer and practically seedless.

The seedlings of Brewer's Gold were, like their parent, rather too late maturing to yield good samples.

Sixteen seedlings of Bullion were examined for P.V. with the following results.

P.V.	*No. of seedlings*
Over 10 per cent. α resin	3
,, 9 ,, ,, ,, ,,	5
,, 8 ,, ,, ,, ,,	2
,, 7 ,, ,, ,, ,,	3
,, 6 ,, ,, ,, ,,	1
,, 5 ,, ,, ,, ,,	1
,, 4 ,, ,, ,, ,,	1

Two samples of Bullion picked and stored under the same conditions gave values of 8·75 per cent. and 7·97 per cent. α resin.

Samples of eleven seedlings of Bullion and two of Brewer's Gold were sent to the Brewing Industry Research Foundation at Nutfield for small scale brewing trials, but no results are yet available.

Controlled crosses were made between tetraploid Bullion and six *Verticillium* Wilt tolerant males.

Ten open pollinated triploid seedlings of Eastwell Golding were raised, and a controlled cross made between tetraploid Eastwell Golding and the male hop Reference Number OB21. It was from a cross between this male, and diploid Canterbury Golding that the varieties Northern Brewer and John Ford were produced.

Resin Glands on Anthers

Work was continued in an effort to discover any relationship between the number of resin glands occurring on the anthers of male hops and the amount of resin in the cones of related female hops.

Two female varieties having high and low P.V. respectively have been crossed with a male hop having a large number of resin glands per anther and another male with very few glands per anther. The families raised from these crosses should indicate whether there is any correlation between P.V. in the females and number of glands per anther in the male hop.

A considerable number of plants, particularly those of American or Canadian parentage, were found to be monoecious. Male flowers were examined and the number of glands per anther determined while samples of hops were collected and resin content determined. There appeared, however, to be no correlation between the resin content of the hops and the number of glands per anther on the same plant. If these two characters are controlled by the same genes a definite correlation would be expected.

The number of glands per anther has so far been the sole criterion in evaluating the male hops in this experiment. It is thought that possibly the size of the resin glands should also be considered in relation to the size of the anthers. Such an assessment would unfortunately be more difficult and statistically less accurate.

New Varieties

Professor E. S. Salmon reports that numerous applications were received for sets of the *Verticillium*-Wilt tolerant (resistant) variety "Bramling Cross" (OT48). Several growers with Wilt-infested farms reported that the growing of the Fuggle variety "is no longer an economic proposition in the district". Rooted sets, in small quantity, were supplied to thirty-four of these growers.

Twelve new seedlings were sent to East Malling Research Station for a *Verticillium* resistance trial; one of these, *Ref. No.* OZ97*a*, has shown resistance (tolerance).

Samples of forty-six New Seedlings, of various parentages, were collected and dried and submitted to a Merchant and to a Brewer for evaluation on aroma and commercial promise. Chemical analyses were made by Mr. E. W. Weston, B.Sc.; several of the seedlings gave high percentages of soft resins, with two over 9 per cent. five over 8 per cent., and five over 7 per cent. α-resin. There are indications that seedlings, of commercial promise and earlier in season than their parents, can be raised from "Northern Brewer" and "John Ford Hop"; one seedling, Reference Number W.F.G.25, is ripe towards the end of August.

Propagation has been carried out of twenty seedlings, showing commercial promise, of varied parentages considered likely to give

resistance to *Verticillium*-Wilt; thirty rooted sets of each have been supplied to East Malling Research Station for use in a *Verticillium* resistance trial in 1954.

Commercial Growth of New Varieties

The production of New Varieties which have been introduced commercially showed only a very small increase in 1953. The following information as to (1) the crop marketed by Registered Producers in 1953 and (2) the acreage in June, 1953, of the varieties, has been supplied by the Hops Marketing Board.

Crop		
1952	6,101 pockets	approx. 9,151 cwt.
1953	6,137 ,,	,, 9,205 ,,

The 6,137 pockets marketed in 1953 consisted mainly of Keyworth's Midseason (OR55), 2,227 pockets; Brewer's Gold (C9*a*), 1,216 pockets; Bullion Hop (Q43), 789 pockets; Early Promise (X35), 608 pockets; Northern Brewer (WFB135), 285 pockets; Keyworth's Early (OJ47), 229 pockets; Pride of Kent (170*a*), 139 pockets; Sunshine (V94), 102 pockets; Quality Hop (OO63), 93 pockets; John Ford Hop (WFA90), 84 pockets. Small amounts of the following varieties were grown: Malling Midseason (BB28); Concord (OH44); Brewer's Standby (HH44); Early Choice (FF21); College Cluster (N15 *bis*); Brewer's Favourite (OP21); Bramling Cross (OT48); Norton Court Golding (WFG19); Copper Hop (OK40;) OF27.

Acreage (in plant June, 1953)

Variety	*Acres*
Class 1: intolerant (susceptible) to *Verticillium* Wilt	
Brewer's Gold (C9*a*)	228·4
Bullion Hop (Q43)	149·2
Early Promise (X35)	96·6
Northern Brewer (WFB135)	48·4
Pride of Kent (170*a*)	16·2
Sunshine (V94)	11·4
Quality Hop (OO63)	10·1
College Cluster (N15 *bis*)	7·9
John Ford Hop (WFA90)	7·2
Brewer's Standby (HH44)	7·0
Concord (OH44)	6·3
Brewer's Favourite (OP21)	5·7

Malling Midseason (BB28)	4·1
Early Choice (FF21)	3·0
Norton Court Golding (WFG19)	2·8
OF27	1·5
AGG8	1·0
OK40	0·2
ON78	0·1
Unspecified Varieties	31·2
	638·3

Class 2: tolerant (resistant) to *Verticillium* Wilt

Keyworth's Midseason (OR55)	513·1
Keyworth's Early (OJ47)	78·4
C2 (E.M.R.S.)	4·0
Bramling Cross (OT48)	3·3
D1 (E.M.R.S.)	0·5
Grand Total	1,237·6

THE CHALLENGE CUPS FOR NEW VARIETIES OF HOPS

Professor E. S. Salmon

This Competition is now divided into three Classes: (1) The Brewers' Cup, for hops intended as substitutes for American hops; this Challenge Cup was offered in 1944 by Messrs. Barclay, Perkins, Messrs. Guinness and Messrs. Whitbread; (2) the Growers' Cup, for hops intended to augment English commercial varieties; this Cup was offered in 1946 by the Association of Growers of the New Varieties of Hops; (3) the Hop Merchants' Association's Cup, offered in 1949 by this Association, for New Varieties certified as showing resistance to *Verticillium* Wilt.

The tenth Competition was held, under the auspices of the Institute of Brewing, in the showrooms of Messrs. Wigan, Richardson and Co., 15 Southwark Street, London, on 19th and 20th November, 1953, the Judges being Mr. Dudley Le May, Mr. A. E. Quin and Lieut.-Col. F. N. Richardson, T.D. A "List of Entries" is given in Tables 1-3, together with the analyses which were carried out at Wye College, in November, 1953, by Mr. E. W. Weston, B.Sc.

The Brewers' Cup (Table 1) was awarded to Furnace Farms, Ltd., for a sample of Bullion Hop (Q43), with an analysis of 10·45 per cent. α acid and 11·51 per cent. β resins. This grower won the Cup in 1952 with Bullion Hop. The Second Place was given to Bullion Hop grown by Mr. T. E. Wimshurst; this sample gave 9·42 per cent. α acid and 11·00 per cent. β resins.

The Growers' Cup was awarded to Mr. J. Nott for a sample of Northern Brewer (WFB135) with the excellent analysis of 10·01 per cent. α acid and 10·51 per cent. β resins, the highest for this variety. We are informed that this growth was picked by machine. All the samples of Northern Brewer exhibited gave high analyses, as did John Ford Hop (WFA90). These two varieties are esteemed by brewers in this country and abroad for their high preservative properties (P.V.), and the demand much exceeds the supply. The acreage planted is at present small, 48·4 acres for Northern Brewer and 7·2 acres for John Ford Hop. The latter Variety gives a higher yield, but is slightly more susceptible to Downy Mildew. Now that

the Hops Marketing Board has raised the valuation of both Varieties to the Golding class, an increase in acreage may be expected.

The Second Place was given to a sample of Sunshine Hop (V94) grown by J. F. Bomford, Ltd., with the good analysis of 6·74 per cent. α acid and 11·84 per cent. β resins. The same Variety exhibited by the same grower was given Second Place in 1952. Sunshine Hop, with its remarkably compact cones, is ideal for machine-picking.

The Third Place was given to Norton Court Golding (WFG19) grown by Mr. J. Nott.

All the samples of Pride of Kent (170*a*) exhibited showed a side full of "condition" and gave excellent analyses, being high both as regards the α acid resin and the β resins, characteristic of this Variety.

Some excellent samples of Early Promise (X35) were shown, two samples giving analyses of 8·33 per cent. and 7·76 per cent. α acid, a preservative value substantially higher than that of the Fuggle Variety. Early Promise is a useful variety; it is early in some districts, though midseason in others, and when picked ripe has good "condition" as shown by analysis. It is decidedly resistant to Downy Mildew as regards "burr" and cones, and also to "mould".

The Cup for varieties resistant to *Verticillium* Wilt was awarded to Brian H. Day, Ltd., for a sample of Bramling Cross (OT48), which had the very satisfactory analysis of 8·20 per cent. α acid and 9·09 per cent. β resins.

TABLE I

ENTRIES FOR BREWERS' CHALLENGE CUP, 1953.

Variety and Grower	Parish	Hops moisture-free	
		α acid %	β fraction %
Bullion Hop (Q43)			
E. M. Gorst	Brenchley, Kent	10·65	11·69
*Furnace Farms, Ltd. ..	Lamberhurst, Kent	10·45	11·51
Wm. Rogers & Son	Horton Kirby, Kent	9·47	10·56
†T. E. Wimshurst	Brenchley, Kent	9·42	11·00
R. D. Wickham	Brenchley, Kent	9·20	11·47
‡Wm. Alexander (Eynsford), Ltd.	Eynsford, Kent	8·75	8·50
J. A. Worley	Chart Sutton, Kent	8·43	10·47
B. P. Tompsett	Yalding, Kent	8·39	11·16
A. Guinness, Son & Co., Ltd.	Teynham, Kent	8·32	10·59
J. Nott	Tenbury, Worcs.	7·85	11·02
J. F. Bomford, Ltd. ..	Fladbury, Worcs.	7·26	10·14
Brewer's Gold (C9*a*)			
J. A. Worley	Chart Sutton, Kent	9·84	11·09
A. S. Mercer	Tonbridge, Kent	9·53	12·16
‡Wm. Alexander (Eynsford), Ltd.	Eynsford, Kent	8·98	10·05
R. D. Wickham	Brenchley, Kent	8·92	10·22
Wm. Skinner & Son ..	East Sutton, Kent	8·84	11·06
A. Guinness, Son & Co., Ltd.	Teynham, Kent	8·52	10·14
E. L. Worsfold	East Sutton, Kent	8·50	9·57
Kennington Hall Farms ..	Wye, Kent	8·02	10·13
A. & K. J. Amos	Wye, Kent	7·78	12·35
Malling Midseason (BB28)			
B. P. Tompsett	Yalding, Kent	7·74	11·89
J. F. Bomford, Ltd. ..	Fladbury, Worcs.	5·79	11·74
College Cluster (N15 *bis*)			
J. F. Bomford, Ltd. ..	Fladbury, Worcs.	5·88	5·99

* Awarded Cup † Placed Second ‡ Tied for Third Place.

TABLE 2

ENTRIES FOR GROWERS' CHALLENGE CUP, 1953.

Variety and Grower	Parish	Hops moisture-free	
		α acid %	β fraction %
Northern Brewer (WFB135)			
*J. Nott	Tenbury, Worcs.	10·01	10·51
H. Veall	Capel, Kent	9·75	8·01
A. & K. J. Amos	Wye, Kent	9·31	8·86
H. Veall & Son	Tudeley, Kent	9·14	9·61
J. A. Worley	Chart Sutton, Kent	8·22	8·51
Pride of Kent (170*a*)			
B. P. Tompsett	Brenchley, Kent	9·72	11·50
H. Veall	Capel, Kent	9·17	13·21
A. & K. J. Amos	Wye, Kent	8·39	12·25
J. F. Bomford, Ltd. ..	Fladbury, Worcs.	7·27	12·50
John Ford Hop (WFA90)			
T. E. Wimshurst	Brenchley, Kent	9·69	10·35
Early Promise (X35)			
B. P. Tompsett	Yalding, Kent	8·33	7·82
Wm. Skinner & Son ..	East Sutton, Kent	7·76	8·25
R. D. Wickham	Brenchley, Kent	6·73	7·01
J. F. Bomford, Ltd. ..	Fladbury, Worcs.	5·98	7·55
Sunshine Hop (V94)			
†J. F. Bomford, Ltd. ..	Fladbury, Worcs.	6·74	11·84
Norton Court Golding (WFG19)			
‡J. Nott	Tenbury, Worcs.	5·59	9·46
Concord Hop (OH44)			
J. F. Bomford, Ltd. ..	Fladbury, Worcs.	5·52	14·93
Day's Early Fuggle			
J. Day & Sons	Staplehurst, Kent	5·00	8·41

* Awarded Cup. † Placed Second. ‡ Placed Third.

TABLE 3

ENTRIES FOR HOP MERCHANTS' ASSOCIATION'S CHALLENGE CUP, 1953.

Variety and Grower	Parish	Hops moisture-free	
		α acid %	βfraction %
Bramling Cross (OT48) Brian H. Day, Ltd.	Marden, Kent	8·20	9·09
Keyworth's Midseason (OR55) H. O. Champneys	Lamberhurst, Kent	7·70	9·01

A SURVEY OF HOP PICKING MACHINES, 1953

INTRODUCTION AND REVIEW OF PREVIOUS SURVEYS

F. C. Thompson

The increasing interest shown in the machine-picking of hops was responsible for initiating a survey of picking machines in 1950. In this year a small-scale survey was made, primarily with the object of establishing a suitable technique for carrying out subsequent investigations.

In 1951 a full-scale survey was undertaken by a team of students from Wye College. Twelve machines of various types, manufactured by either the McConnell-Hinds or Bruff companies, were studied. Detailed information was obtained on machine management and on the organization adopted in the hop yard for collecting and handling the hop bines before picking. Data were also obtained on the amount of breakage found in the final sample of picked hops, on the amount of extraneous matter present in the sample, and on resin losses.

At the request of interested growers, and also to get some measure of the effect of seasonal conditions on machine performance, the survey was repeated in 1952 on essentially the same lines as in 1951. The only new feature in 1952 was an attempt to get some comparison between machine picked and *commercially* hand picked hops with regard to cone breakage and resin loss.

As a result of the surveys carried out in 1951 and 1952 much useful information has been made available on hop yard organization and machine management and many growers have taken advantage of this information in modifying their own techniques. In particular attention has been drawn to the necessity of bringing the hops to the machines in an undamaged condition and in such a manner as to enable the bines to be unloaded easily and efficiently—an important factor in preventing excessive breakage of laterals in the machine. The method of physical analysis developed has enabled comparisons to be made, on a defined basis, both between samples, from different machines and through the picking period on any one machine, and has been of value in assisting growers to assess the standard of their

machine picking. The amount of waste from the machine has been found to show some correlation with the extraneous matter present in the final sample of hops—i.e. "the cleaner the sample, the greater the waste" is, in general, true. The comparison of labour forces and organization on different machines has shown the need for factory methods in the machine shed and the necessity for a competent man to be in charge of both the machine and yard organization. Satisfactory output and a good final sample can only be obtained by a continuous, but unhurried, flow of hops through the machine. Full reports on the surveys have been presented to the Agricultural Research Council and published in the Annual Reports of the Department of Hop Research, Wye College, for 1951 and 1952. These reports have also included descriptions of the machines studied, and, in fact, one of the initial aims of the survey was to make a comparison between the performance of the various machines then thought to be available to growers. Most of these machines have, however, never developed beyond the prototype stage and for all practical purposes the only machine to be considered at the present time is the one made by the Bruff Company.

By 1953 it was felt that no useful purpose would be served by a repetition of the studies on hop yard organization, and on the labour and general machine management aspects of the survey, and the question of comparing the performance of different machines in commercial operation did not arise. The data obtained on resin losses and cone damage had, however, been very variable and difficult to interpret and it was thought that sampling errors probably accounted for this. It was, therefore, suggested that in 1953 a replicated sampling technique should be adopted to give results which could be subjected to statistical analysis. In addition, evidence had been accumulating during the course of the surveys that the drying of machine picked hops presented special problems, and to study this it was thought desirable to follow-up samples from the machine, through the drying process, and up to the stage of marketing in the Borough. A further point arising by 1953 was the introduction of machines into the South Eastern hop growing area. Up to this year, machine picking had been largely confined to the West Midland area, but was now found to be extending rapidly in Kent. In consequence it was decided to organize a separate survey in Kent designed to be complementary to that in the West Midlands area. This concentrated on a more detailed study of a much smaller number of machines, and included measurements on wastage, and a careful comparison between machine picking and commercial hand picking at all stages.

AN ACCOUNT OF THE SURVEY IN THE WEST MIDLAND AREA

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General Information Relating to Machines

In 1950, hop-picking machines were few in number, only 11 Bruff and 10 McConnell-Hinds machines being in operation on grower's farms. Brewer-growers had 3 McConnell-Hinds and some prototype pickers in operation, but machines on these farms have not been included in the surveys. By 1953 considerable expansion had taken place, there being 62 Bruff machines installed on growers' farms, 5 of them in Kent. Information at present to hand suggests that a further 22 Bruff machines will be installed in 1954, 18 of which will be in Kent.

Of the other machines the McConnell-Hinds, in its original form, has gone out of production, but Mr. Hinds is now working on the development of a new picking mechanism, though as yet no details are available. The Strettle and Burr mobile machine, which had advanced far in the prototype stage, is now likely to be held up owing to the two principals of the firm having dissolved partnership. The Harvestex machine which has been in the prototype stage for several years, does not yet appear to have reached any finality of design, while the Lewis and Shotton mobile picker was only a first year prototype in 1953. There are also one or two other machines in less advanced stages of development.

A description of the various types of Bruff machine has been given in previous reports, but modifications are continually being introduced. In 1953 the popular "Type B" machine was modified by the introduction of a new type of lateral picker which, in turn, necessitated the reintroduction of the central roller conveyor to receive the laterals moving forward from the main picking mechanism. The new lateral picker consisted of thin wire loops attached to steel bars fixed to an endless chain. Two such chains, placed vertically and revolving in opposite directions, picked off the hops from laterals held between two tightly fitting chains moving in a horizontal plane. Each lateral was placed by hand between the horizontal chains and having passed through the picking loops, was discharged on to a

waste conveyor, the picked hops being conveyed back into the main hop stream. One lateral picker was placed at the rear (feed) end of the machine to deal with all the loose laterals and material collected in the yard, and two more lateral pickers were placed in the centre of the machine, adjoining the roller conveyor. Finally all small bunches and unpicked laterals on this latter conveyor, which were not dealt with by the lateral pickers, were placed by hand on a small roller picker.

A modification introduced into the main picking drums was the replacement of four of the six rows of straight fingers by wire loops. In addition, a special gear was incorporated to enable the speed of these drums to be varied independently of the rest of the machine, and an outlet was fitted to enable separated petal to be excluded at will from the final product.

Details of the 1953 Survey

Ten of the machines (A, B, D, E, F, G, H, M, N and P) studied in 1952 were included in this Survey, while two (R and S) were new machines installed in 1953.

The output of each machine was sampled as far as possible on six occasions, during one day per week for three weeks. Each sample was physically analysed into five parts, as in 1952. At each visit three samples of machine picked hops, and three samples of comparable whole hops carefully picked by hand, were dried in muslin bags and sent to Wye for chemical analysis for Total Soft Resin content. At the time of collecting one of these samples, green sacks were marked so that the kiln loads could be identified and a sample subsequently taken from the appropriate pockets. These samples were also analysed for Total Soft Resins and for extraneous matter.

On two machines (F and R) samples were taken at various points along the machine as the process of picking and cleaning progressed. These were analysed for Total Soft Resins and one sample through the machine was also physically analysed.

The large mass of figures obtained from both the physical and chemical analysis of the samples taken in the course of this survey, have been summarized in Table 1 for presentation in this paper, since the data are essentially the same as those presented in previous machine survey reports (1952, 1953), but are drawn from a much larger number of samples. The conclusions drawn from the data, however, are discussed below and the figures themselves are available in typescript, at Wye, for consultation by any interested grower.

Summary of the Statistical Analysis of the Data obtained in 1953

The data for the physical analysis of the samples collected was first examined. This was the data obtained by taking up to six samples on one occasion in each of three weeks, on 10 machines in all. The samples were separated into whole hop, broken hop, petal and seed, and "extraneous matter" (leaf plus stem). Significant differences were found, in each category, for "between machines" and "between weeks". In effect this just confirms statistically, what had been deduced from previous surveys, i.e. that there is a marked difference between the performance of different machines, and with any one machine, that there is a difference in performance at different stages through the picking season. Statistical analysis also showed that for the figures obtained to be significant to within even 10 per cent. of the mean, sampling of each machine would have to be carried out on a much larger number of occasions than was the case with the 1953 survey. This is not a practical possibility with this large scale type of survey and the conclusion is that for this type of detailed work frequent sampling of one, or at most two, machines is necessary.

Indices of breakage were calculated from the physical analysis data; these were "A"—Petal and Seed/Total Hop and "B"—Leaf and Stem/Total Sample. Resin analyses were made (for Total Soft Resins) on samples of special hand-picked hops taken from bines just prior to entering the picking machine and on samples taken at the end of the picking machine. This gave a measure of loss of resin through the machine, though in fact, in some cases there was an apparent gain; this could only be attributed to sampling errors. No correlation could be found between any measure of breakage of the hop cones and resin loss, as determined by the sampling technique adopted in this survey.

Sampling of Machines through the Picking and Cleaning Processes

As stated above, on two machines (F and R) samples were taken at various points along the machine as the process of picking and cleaning progressed, the results obtained being shown in Table 2.

Physical analysis tended to show that the main picking mechanism, and the new lateral picker fitted to the Bruff "B" machine in 1953, produced similar results as far as "quality" of picking was concerned. Chemical analysis showed that the loss of resin at these points was lower than expected.

The loss of resin found in the "petals only" fraction, after the material had passed through the fan cleaner, was apparently very high, but it was not clear whether this loss was directly attributable to the effect of the air draught. It is possible that the inclusion of this material in the final sample may have a diluting effect on the Total Soft Resin content.

It would appear that the chief method of improving the picking machine lies in the design and use of the actual picking mechanism.

Examination of Hop Samples taken from the Pocket in the Borough

Physical analysis of the pocket samples showed that of the extraneous matter present, the stem represented a larger proportion by weight than did the leaf. Thus a sample with little stem present in the total weight of extraneous matter appeared less cleanly picked than a sample containing an equivalent weight of waste, but largely made up of stem.

The method used in analysing the samples for extraneous matter was tested out on samples of American hops for which such data were already available and was found to agree very well.

It was found that really clean samples of English machine picked hops could have an extraneous matter content of only 2·4 per cent. while at the other extreme the content could rise to 18 per cent. A small selection of hand picked samples examined gave a range of 3·7 per cent. to 14 per cent. Less leaf was generally found in machine picked samples as compared with corresponding hand-picked hops, but the presence of more stem waste increased the actual *weight* of extraneous matter present.

Conclusions

It is considered that the surveys carried out have been very useful in providing information on the management aspects of machine picking, and the general conclusions drawn now form the basis for advisory recommendations to hop growers. Further investigations on these lines would not, it is felt, serve any useful purpose at the present time.

At the same time it must be stressed that no hard and fast rules for "management" of the machine can be laid down, since this may be governed by market demand. Thus, on a falling market, it may well pay the grower to waste a relatively high proportion of hops and so produce a very clean and attractive looking sample, rather than to

aim for maximum output with consequent deterioration in the quality of the final sample.

A fruitful line for development would be an intensive study of the machine itself, with the aim of improving the various stages of the picking and cleaning process, but this is primarily an engineering problem which might best be undertaken by the manufacturers or by an organization such as the National Institute of Agricultural Engineering.

The surveys have emphasized the need for "growing the hops for the machine". This can be approached in a number of ways:

(*a*) By modifying cultural methods (e.g. height of wirework and width of spacing) so as to produce the type of growth most suitable for machine picking.

(*b*) By extending the "season" of the hops grown so that the crop coming forward to the machine is at the stage of maturity when the cones are least liable to damage—e.g. by selection of cones of established varieties, which ripen at different dates through the picking season.

(*c*) By the development of seedless hops (e.g. by polyploidy) which pick better by machine.

(*d*) By growing certain of the New (Wye) Varieties of hops which have been found, owing to their botanical structure, to be much more suitable for machine picking than the older commercial varieties.

Work on these lines is being developed at the Hop Research Department at Wye, and it is noteworthy that certain of the New (Wye) Varieties produce samples containing a much higher percentage of whole hops than is obtained with the Fuggle variety. In the 1953 survey, for example, with Fuggle the "whole hop" percentage ranged from 22 per cent. to 54 per cent., with most of the samples falling in the 30-40 per cent. category, while with the Mathon variety the figure rose to 60 per cent. and with the New (Wye) Varieties Bullion and Pride of Kent, figures of about 75 per cent. were obtained. It must not be overlooked, however, that if major improvements in the mechanical processes of picking and cleaning are a practical possibility, then much of such research would become redundant.

The surveys have also shown that the drying of machine picked hops presents special problems. This is largely influenced by the degree of breakage of the hops, since it has been found that the

separated parts of the hop cone dry at very different rates to the whole hops. Experiments are also being carried out at Wye to investigate the requirements for drying machine picked hops.

The need for extra care in handling the hops in the oast and for a good kiln technique has been clearly demonstrated. For example, it is quite possible for a well picked sample from the machine, containing 50 per cent. whole hops, to be handled in such a manner during the drying and pressing processes that no more whole hops are found in the final pocket sample than with a sample coming from the machine with only 30 per cent. whole hops.

Future Survey Work

It is considered that little further work can be carried out at present which is likely to be of value to the user of the one picking machine commercially available. It is possible, however, that in a few years time the number of machines which have been put on a commercial basis may be such as to warrant a further survey being undertaken.

The present surveys have stimulated lines of research into cultural methods of growing the hops for the machine; the development of clonal selections of established hop varieties with a range of seasons: the production of seedless hops by polyploidy; the further development of new varieties more suitable for machine picking; and the technique required for drying machine picked hops. All these lines of work are now being followed up at the Hop Research Centre at Wye.

Detailed improvements of the picking and cleaning mechanisms incorporated in the Bruff machine are felt to lie within the province of the manufacturers or an establishment for research in Agricultural Engineering.

Acknowledgments

Though the writer has been primarily responsible for the detailed organization and carrying out of all the machine surveys in the West Midland area, acknowledgment is due to a number of colleagues for help in the design of the surveys and in some instances for practical help in the field. These include the lecturers in Agricultural Engineering at Wye College, Mr. J. A. C. Gibb and his successor, Mr. J. N. Merridew, and Mr. A. E. Maddison, statistician at Wye College, who advised on the statistical layout of the 1953 survey and on the interpretation of the results obtained. The general co-ordination of

the surveys has been the responsibility of the officer in charge of the Hop Research Department at Wye—for the early years of the survey this was Dr. A. H. Burgess as Head of the Department and latterly has been Mr. F. C. Thompson as Acting Head.

Acknowledgments are also due to the Agricultural Research Council for arranging for the provision of funds for the employment of student labour recruited from Wye College, and to those hop growers who have so readily provided facilities for investigations to be made on their picking machines.

ABBREVIATIONS USED IN TABLES

W.H. Whole Hops.
B.H. Broken Hop. Any Hop with more than two petals missing.
P & S. Loose petals, Hop Strig (Rachis) without petals attached. Loose seed.
L. Leaf.
S. Leaf Stem (Petiole) and/or hop stems when more than 1″ long.
B.P. Hops picked by hand before entering machine.
A.P. Hops picked by machine.

TABLE 1

AVERAGE VALUES FOR PHYSICAL AND CHEMICAL ANALYSIS OF HOP SAMPLES TAKEN IN THE WEST MIDLAND PICKING MACHINE SURVEY, 1953.

Machine Code Letter and description	Hop Variety	Sampling Time	Machine Sample								Pocket Sample	
			Physical Analysis					Total Soft Resin			L and S	Total Soft Resin
			WH	BH	P and S	L	S	BP	AP	Loss		
		Week										
"A" Medium Bruff	Fuggle	1st	34·1	32·9	26·8	5·9	0·3	13·56	11·07	−2·49	13·2	11·75
		2nd	33·2	33·3	26·8	6·0	0·7	14·63	11·08	−3·55	12·7	12·76
		3rd	28·4	34·7	30·5	5·6	0·8	14·00	11·44	−2·56	11·1	12·50
"B" Medium Bruff	Fuggle	1st	41·9	33·0	18·0	6·0	1·1	11·93	12·03	+0·10	8·0	11·77
		2nd	32·9	38·3	22·7	5·4	0·7	12·71	11·69	−1·02	11·7	12·03
		3rd	38·3	34·4	21·5	4·7	1·1	12·18	11·94	−0·24	8·5	13·05
"D" Large Bruff	Fuggle	1st	29·5	38·2	23·7	8·1	0·5	13·91	11·70	−2·21	9·5	12·78
		2nd	36·4	44·6	12·5	5·9	0·5	12·06	12·16	+0·10	9·0	12·74
		3rd	46·9	45·2	4·2	2·9	0·8	14·99	12·71	−2·28	5·1	13·93
"E" Large Bruff	Fuggle	1st	38·0	33·8	17·1	7·6	3·5	13·01	11·91	−1·10	13·8	9·42
		2nd	40·4	37·9	11·8	7·6	2·3	13·66	11·88	−1·78	9·5	10·76
		3rd	30·0	40·9	21·5	5·7	1·9	13·61	10·26	−3·35	9·4	10·43
"G" Large Bruff	Fuggle	1st	45·1	50·5	2·5	1·0	0·9	14·66	13·47	−1·19	3·1	13·47
		2nd	36·3	39·5	19·9	3·8	0·5	15·27	11·57	−3·70	3·0	12·92
		3rd	34·7	37·9	22·8	4·1	0·4	13·34	11·74	−1·60	5·9	13·15
"H" Large Bruff	Early Bird	1st	51·0	31·8	9·0	4·4	3·7	15·95	14·22	−1·73	9·5	12·75
		2nd	54·4	36·0	5·4	2·3	1·9	15·84	12·28	−3·56	5·1	14·10
		3rd	56·6	29·8	9·4	2·7	1·5	15·29	14·33	−0·96	7·4	13·04
"M" Bruff Model "B"	Fuggle	1st	45·4	31·8	12·4	9·8	0·6	14·59	13·50	−0·99	8·1	11·99
		2nd	53·4	35·3	7·3	3·6	0·4	13·88	12·86	−1·02	5·4	11·95
		3rd	51·5	41·2	5·2	1·6	0·4	13·20	11·84	−1·36	3·0	12·66
"N" Bruff Model "B"	Fuggle	2nd	52·9	38·0	6·2	2·5	0·4	14·13	10·87	−3·26	6·6	12·73
		3rd	45·7	34·3	15·4	4·2	0·4	15·69	12·99	−2·70	4·4	13·61
"P" Composite Machine	Fuggle	1st	28·8	38·0	21·5	8·8	2·9	13·64	13·00	−0·64	13·3	11·31
		2nd	28·0	46·0	19·1	4·2	2·6	13·38	12·96	−0·42	8·3	11·32
		3rd	21·5	45·6	24·5	4·7	3·7	14·27	12·16	−2·11	10·7	10·43
"S" Bruff Model "C"	Fuggle	1st	48·4	27·9	14·3	7·9	1·4	15·34	11·05	−3·29	13·2	12·60
		2nd	38·6	36·5	15·6	7·2	2·1	13·31	11·38	−1·93	18·1	11·99
		3rd	31·3	36·7	23·9	6·7	1·4	13·33	11·85	−1·48	10·0	11·85

TABLE 2

AVERAGE VALUES FOR PHYSICAL AND CHEMICAL ANALYSIS OF HOP SAMPLES TAKEN AT VARIOUS POINTS THROUGH THE PICKING MACHINE.

Machine Code Letter and description	Hop Variety	Sampling Time	Machine Sample								Pocket Sample	
			Physical Analysis					Total Soft Resin				
			WH	BH	P and S	L	S	BP	AP	Loss	L and S	Total Soft Resin
		Week		Final Sample								
"F" Large Bruff	Fuggle	1st	41·3	41·8	12·5	3·4	1·1	12·69	12·46	−0·23	5·5	12·28
,,	Mathon	2nd	58·9	32·2	5·3	2·9	0·6	12·69	10·47	−2·22	3·2	12·11
,,	Mathon	3rd	61·1	31·6	4·7	2·0	0·6	11·26	11·57	+0·31	3·1	12·10
				Fan Cleaned								
,,	Fuggle	1st	47·8	43·5	3·9	3·9	0·9		12·04			
,,	Mathon	2nd	69·8	25·5	1·5	1·5	1·5		11·38			
,,	Mathon	3rd	49·3	40·4	4·1	2·0	4·2		11·78			
				Petals Only								
,,	Fuggle	1st		1·3	85·9	13·6			7·88			
,,	Mathon	2nd	0·7	0·7	57·0	40·9	0·7		23·56			
,,	Mathon	3rd		3·8	72·7	22·6	0·9		7·70			
				Plucker Only								
,,	Fuggle	1st	23·9	26·5	20·5	27·1	2·0		10·18			
,,	Mathon	2nd	46·3	25·8	7·7	18·3	1·9		10·18			
,,	Mathon	3rd	40·3	29·1	11·9	17·1	1·5		9·65			
				Lateral Picker								
,,	Fuggle	1st	31·0	29·6	13·4	21·8	4·2		10·59			
,,	Mathon	2nd	50·0	26·6	3·2	18·1	2·1		11·77			
,,	Mathon	3rd	34·9	26·1	13·0	21·2	4·8		10·17			
				Rollers Only								
,,	Fuggle	1st							8·77			
				Lateral Roller								
,,	Mathon	3rd	24·3	29·6	13·0	26·1	7·0		11·24			

TABLE 2 (*Continued*)

Machine Code Letter and description	Hop Variety	Sampling Time	Machine Sample								Pocket Sample	
			Physical Analysis					Total Soft Resin				
			WH	BH	P and S	L	S	BP	AP	Loss	L and S	Total Soft Resin
		Week		Final Sample								
"R" Bruff Model "B"	Early Choice Early Bird	1st	61·9	31·9	3·5	2·0	0·9	14·38	14·15	−0·23	5·2	14·46
,,	Mathon	2nd	67·3	26·0	4·6	1·9	0·3	15·42	13·87	−1·56	4·7	15·49
,,	Pride of Kent Sunshine Bullion	3rd	74·5	20·4	1·9	2·9	0·4	20·81	18·92	−1·89	2·9	19·61
				Fan Cleaned								
,,	Early Choice Early Bird	1st	58·8	34·5	0·7	3·7	2·3		13·77			
,,	Mathon	2nd	68·9	27·6	0·7	1·9	0·5		13·37			
,,	Pride of Kent Sunshine Bullion	3rd	70·5	22·2	1·0	5·6	0·9		17·17			
				Plucker Only								
,,	Early Choice Early Bird	1st	47·5	26·2	5·6	20·3	0·4		12·80			
,,	Mathon	2nd	52·6	19·4	9·4	18·3	0·3		12·91			
,,	Pride of Kent Sunshine Bullion	3rd	57·0	16·8	7·3	18·7	0·3		16·66			
				Lateral Picker								
,,	Early Choice Early Bird	1st	39·2	31·2	6·0	21·6	2·0		10·36			
,,	Mathon	2nd	25·9	24·7	12·3	33·9	3·2		12·89			
,,	Pride of Kent Sunshine Bullion	3rd	51·1	12·7	9·1	27·2	1·1		17·26			

INVESTIGATION OF HAND- AND MACHINE-PICKING OF HOPS IN KENT, 1953

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Introduction

This investigation is complementary to that carried out in the West Midlands. It was made on an *in*tensive rather than an *ex*tensive scale, being designed to provide a more complete picture of all processes at relatively few sites.

The former machine-surveys in the West Midlands had concentrated on the condition of the *green* hops, and it was felt that more information about the condition of the *dried* hops would be valuable, particularly in relation to the amount of wastage involved. A small pilot investigation to work out techniques had been carried out in 1952, and provided a basis for the design of the 1953 investigation.

Aims

(1) To compare machine picked hops with comparable hand picked hops at all stages from picking to pocket, and to measure at the same time the amount of wastage involved in the production of these samples.
(2) To assess the effects of the picking and drying processes separately on the breakage of hand and machine picked hops.

The investigation falls into two broad divisions. The first series (A) was carried out on *ripe* Fuggles and consisted of:

(1) Machine picked samples taken on a dry day (14th September).
(2) Hand picked samples on the same farm taken on the following day which was also dry.
(3) A further series of samples from the same machine, but taken from a different garden and on a damp day following rain in the night.

The second series (B) was carried out a week later on *over-ripe* Fuggles. A different machine was involved, and the comparable hand picking had to be done on another farm, though this was in the

same district and the same strain of Fuggle was involved. The hand picking was, however, done three days later than the machine picking at a time when every day made a difference to the condition of the hops, so that the two types of picking are not so closely comparable as in the first series (A).

METHOD

The procedure followed was to spend one day on the farm taking the samples and measurements and carrying out the physical analyses and weighing of certain of the smaller samples of wastage. Most of the samples, however, had to be taken back to the laboratory in closed tins, and the physical analyses and weighing of the parts were subsequently done there. Thus, although some of the *green* hops samples were the equivalents to those taken in the West Midlands survey and their physical analyses were made on the same basis, the figures for the two areas are not quite comparable since in Kent the transport back to the laboratory before analysis meant that the hops were subjected to further breakage.

The samples taken were:

Machine

Hop Samples

(1) Samples of final output: (*a*) For physical analysis green. (*b*) For protected drying in muslin bags.
(2) Samples of machine picked hops at the time of loading the kiln.
(3) Samples of whole hops taken at various points on the same trailer load for protected drying in muslin bags.
(4) Samples of commercially dried hops at the time of pressing.
(5) Samples from the appropriate pockets.

Physical analyses only were made on the green samples, but a chemical analysis for total soft resin was done on all the dried samples as well as a physical analysis. The basis of the physical analysis had to be altered according to the type of sample, but a category described as "recognizable hop" is provided so that samples can be compared on the same basis throughout.

Samples for Wastage

(1) The amount of hop remaining on 10 spent strings (bines).
(2) The amount of hop remaining on spent laterals collected for a timed period (3 minutes).

TABLE 1

SERIES A—RIPE FUGGLE, HAND PICKED. (15th September, 1953.)

(Compare with Tables 2 and 3 for comparable machine picking, and Table 5 for hand picked over-ripe hops.)

(Figures as percentages—in left-hand column percentages of Total Samples in right-hand column percentages of Hop portion only.)

Type of Sample	Physical Analysis									Chemical Analysis	Wastage of Hops		
	Whole Hops $> \frac{1}{2}$ hop	Broken Hops $< \frac{1}{2}$ hop	Total Recognizable Hop	Petal	Seed	Total Petal and Seed	Leaf	Stem	Total Leaf and Stem	Total Soft Resin	Green hops remaining on bines and ground in garden (Average 7 samples)	lb./acre Green Hops	Estimated lb./acre Dried Hops
Dried Hops													
Whole hops; protected drying ..	88·9	1·9	90·8			8·8	—	—	—	14·8			
(Average 2 samples)	88·9	1·9	90·8	—	—	8·8	—	—	—	14·8			
Hand picked; protected drying ..	75·9	4·3	80·2			16·2	2·8	0·1	2·9	14·1			
(Average 3 samples)	78·4	4·5	82·9	—	—	17·2				14·5			
Hand picked; Commercial drying ..	60·5	9·0	69·5			26·8	2·1	0·7	2·8	13·1		146	29
At pressing	62·9	9·4	72·3	—	—	28·1				13·5	Total	146	29
(Average 8 samples)													
Hand picked; Commercial drying ..	—	—	71·2	23·3	2·3	25·6	1·9	1·4	3·3	14·0†			
From pocket	—	—	73·6	24·2	2·4	26·6				14·5			
(*Physical* Analysis—6 samples from 2 pockets)													
(*Chemical* Analysis—2 samples one from each pocket)													
Green Hops													
Hand picked from kiln	70·9*	19·6*	90·5			7·1	1·8	0·6	2·4	—			
At loading	72·7	20·0	92·7	—	—	7·3				—			
(Average 8 samples)													
Hand picked in garden	66·0	23·6	89·6			6·9	2·2	1·0	3·2	—			
At measuring	69·5	24·5	94·0	—	—	7·1				—			
(Average 10 samples)													
	Average all Commercial dried samples		70·0			26·0				13·3			
			73·0			27·0				13·7			
			Average all dried samples				1·6	0·9	3·0				
			Average all green samples				2·0	0·8	2·8				

NOTE: (*a*) Condition of hops—dry.

(*b*) Distance of transport to oast—300 yards.

* Categories for WH and BH as for West Midland Survey, but figures not exactly comparable with those, because samples were taken back to the laboratory for analysis on the following day and were thus subjected to further breakage.

† Figure for pocket samples likely to be less accurate than sample at pressing, since it represents only 2 samples as against 8.

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TABLE 2

SERIES A—RIPE FUGGLE. MACHINE (A) I. (14th September, 1953.)

(Compare with hand picked in Table 1.)

(Figures as percentages—in left-hand column percentages of Total Sample; in right-hand column percentages of Hop portion only.)

Type of Sample	Physical Analysis									Chemical Analysis	Wastage of Hops
	Whole Hops > ½ hop	Broken Hops < ½ hop	Total Recognizable Hop	Petal	Seed	Total Petal and Seed	Leaf	Stem	Total Leaf and Stem	Total Soft Resin	From 2 sources: (a) *In Garden* (hops remaining on ground, cu bines and fallen laterals) Average 8 samples (b) *At Machine* (from 5 points, average 4 sample taken, at same time as hop samples)
Dried Hops											
Whole hops; protected drying ..	89·7	3·7	93·4			6·6	—	—	—	15·7	
(Average 4 samples)	89·7	3·7	93·4	—	—	6·6	—	—	—	15·7	
Machine picked; protected drying ..	78·4	8·0	86·4			10·0	1·8	1·6	3·4	14·1	
(Average 4 samples)	81·3	8·4	89·7	—	—	10·4				14·6	
Machine picked; Commercial drying	55·8	10·6	66·4			30·9	1·6	0·6	2·2	13·3	
At pressing	57·4	10·9	68·3	—	—	31·7				13·6	
(Average 8 samples)											
Machine picked; Commercial drying	—	—	59·1	32·2	5·2	37·4	1·9	1·7	3·6	13·2	
From pocket	—	—	61·3	33·4	5·4	38·8				13·7	
(*Physical* Analysis—4 samples from 2 2 pockets)											
(*Chemical* Analysis—2 samples one each pocket)											
Green Hops											
Machine picked (at machine) ..	54·7*	35·2*	89·9	—	—	5·3	2·1	1·0	3·1	—	
(Average 4 samples)	56·8	37·7	94·5	—	—	5·8				—	
	Average all Commercial dried samples		66·0			33·0				13·3	
			70·0			34·0				13·6	
			Average all dried samples				1·8	1·3	3·1		
			Average all green samples				2·1	1·0	3·1		

Source	lb./acre Green Hops	Esti-mated lb./acre Dried Hops
(a) In garden ..	86	17
(b) At machine		
1. Spent bines	100	20
2. Spent laterals	46	9
3. Fan waste	993	298
4. Sorters waste	13	3
Total unavoidable waste	1,238	347
5. Petal waste (Deliberate)	555	167
Total Waste ..	1,793	514

NOTE: (*a*) Condition of hops—dry.
(*b*) Distance of transport to machine—300 yards. Hops bagged at end of machine and conveyed in pokes by elevator to kiln.
(*c*) Rate of loading machine—Hooks running at 16 per minute. Hooks loaded with single strings only at average rate of 11 per minute.

* See *NOTE*—Table 1

TABLE 3

SERIES A. RIPE FUGGLE. MACHINE (A) II. (17 September, 1953.)

(Compare with Table 1 for comparable hand picking, with Table 2 for another series on same machine.)

(Figures as percentages—in left-hand column percentages of Total Sample; in right-hand column percentages of Hop portion only.)

Type of Sample	Physical Analysis: Whole Hops > ½ hop	Broken Hops < ½ hop	Total Recognizable Hop	Petal	Seed	Total Petal and Seed	Leaf	Stem	Total Leaf and Stem	Chemical Analysis: Total Soft Resin
Dried Hops										
Whole hops; protected drying ..	94·2	0·7	94·9			4·9	—	—	—	15·0
(Average 5 samples)	94·2	0·7	94·9	—	—	4·9	—	—	—	15·0
Machine picked; protected drying ..	83·9	2·8	86·7			10·2	2·1	1·2	3·3	14·6†
(Average 5 samples)	86·7	2·9	89·6	—	—	10·6				15·1†
Machine picked; Commercial drying	62·1	8·5	70·6			26·1	2·5	1·0	3·5	14·0
At pressing	64·3	8·8	73·1	—	—	27·4				14·5
(Average 8 samples)										
Machine picked; Commercial drying	—	—	64·3	27·2	5·0	32·2	2·2	1·5	3·7	13·5
From pocket	—	—	66·9	28·2	5·2	33·4				14·0
(*Physical* Analysis—8 samples from 3 pockets)										
(*Chemical* Analysis—3 samples one from each pocket)										
Green Hops										
Machine picked; at machine ..	66·3*	24·6*	90·9			4·9	2·1	1·7	3·8	—
(Average 5 samples)	69·0	25·8	94·8	—	—	5·2				—
	Average all Commercial dried samples		67·0			29·0				13·9
			70·0			30·0				14·4
			Average all dried samples				2·3	1·2	3·5	
			Average all green samples				2·1	1·7	3·8	

Wastage of Hops

From 2 sources:

(*a*) *In garden*
(Hops remaining on ground, bines and fallen laterals)
Average 5 samples

(*b*) *At machine*
(From 5 points, average 5 samp taken, at same time as samples)

Source	lb./acre Green Hops	Esti mate lb./ac Drie Hop
(*a*) In Garden	130	26
(*b*) At Machine		
1. Spent bines	37	7
2. Spent laterals	48	10
3. Fan waste	590	177
4. Sorters waste	15	3
Total unavoidable waste	820	223
5. Petal waste (Deliberate)	370	101
Total waste	1,190	324

NOTE: (*a*) Condition of hops—*wet* following rain in night and early part of morning—different garden from Series I.
(*b*) Distance of transport to machine—¼ mile.
(*c*) Rate of loading machine—Hooks running at 16 per minute. Hooks loaded with single string only at average rate of 12 per minute.

* See *NOTE*—Table 1.

† These figures are obviously too high because 2 of the 5 samples had Total Soft Resin figures much greater than the whole hops. The discrepancy was probably due to lumps of compacted resin falling into the sample—quite a possibility when the hops are wet. Without these 2 samples the figures would be 13·6 and 14·1.

TABLE 4

SERIES B. OVER-RIPE FUGGLE. HAND PICKED. (25th September, 1953.)

(Compare with Table 1 for hand picked ripe Fuggle and with Table 5 for same type of Fuggle machined picked.)

(Figures as percentages—in left-hand column percentages of Total Sample; in right-hand column percentages of Hop portion only.)

Type of Sample	Physical Analysis									Chemical Analysis	Wastage of Hops		
	Whole Hops $>\frac{1}{2}$ hop	Broken Hops $<\frac{1}{2}$ hop	Total Recognizable Hop	Petal	Seed	Total Petal and Seed	Leaf	Stem	Total Leaf and Stem	Total Soft Resin	Green hops remaining on bines and ground in garden (Average 8 samples)		
												lb./acre Green Hops	Estimated lb./acre Dried Hops
Dried Hops													
Whole hops; protected drying ..	87·3	1·9	89·2			10·9	—	—	—	16·8			
(Average 3 samples)	87·3	1·9	89·2	—	—	10·9	—	—	—	16·8			
Hand picked; protected drying ..	57·3	5·4	62·7			32·1	3·3	0·9	4·2	14·6			
(Average 8 samples)	60·2	5·7	65·9	—	—	33·7				15·2			
Hand picked; Commercial drying ..	49·0	8·3	57·3			36·6	4·1	2·1	6·2	14·4		180	30
At pressing	52·0	9·0	61·0	—	—	38·8				15·3			
(Average 8 samples)											Total waste	180	30
Hand picked; Commercial drying ..	—	—	60·0	33·6	2·3	35·9	2·7	1·5	4·2	15·3			
From pocket	—	—	62·6	34·8	2·4	37·2				—†			
(*Physical* Analysis—4 samples from 1 pocket only)													
(*Chemical* Analysis—5 samples one from each of 5 pockets)													
Green Hops													
Hand picked from kiln	41·5*	34·9*	76·4			18·8	3·8	1·4	5·2	—			
At loading	43·5	36·7	80·2	—	—	19·6				—			
(Average 8 samples)													
Hand picked in garden	50·5	29·2	79·7			16·4	3·1	0·7	3·8	—			
At measuring	52·6	30·4	83·0	—	—	17·0				—†			
(Average 8 samples)													
	Average all Commercial dried samples		57·0			37·0				14·4			
			61·0			39·0				15·3			
			Average all dried samples				3·5	1·5	5·0				
			Average all green samples				3·5	1·6	4·5				

* See *NOTE*—Table 1.

† No correction for Hop portion only was made, since the physical analysis on one pocket sample only would not be typical.

TABLE 5

SERIES B. OVER-RIPE FUGGLE. MACHINE (B). (22nd September, 1953.)

(Compare (see footnotes) with Table 2 and 3 for another machine picking ripe Fuggle and compare with Table 4 for roughly comparable hand picking.)

(Figures as percentages—in left-hand column percentages of Total Sample; in right-hand column percentages of Hop portion only.)

Type of Sample	Physical Analysis									Chemical Analysis	Wastage of Hops
	Whole Hops > ½ hop	Broken Hops < ½ hop	Total Recognizable Hop	Petal	Seed	Total Petal and Seed	Leaf	Stem	Total Leaf and Stem	Total Soft Resin	In Garden—records not taken At Machine—5 samples taken at same time as hop samples.
Dried Hops											
Whole hops; protected drying ..	93·0	0·6	93·6			6·6	—	—	—	16·4	
(Average 5 samples)	93·0	0·6	93·6	—	—	6·6	—	—	—	16·4	
Machine picked; protected drying ..	72·5	6·0	78·5			14·9	4·8	1·8	6·6	14·3	
(Average 5 samples)	77·8	6·4	84·2	—	—	16·0				15·3	
Machine picked; Commercial drying At pressing				Not Taken							
Machine picked; Commercial drying From pocket	—	—	28·9 30·8	55·4 58·6	10·7 11·3	66·1 69·9	3·5	1·9	5·4	13·1 13·9	
(*Physical* Analysis—8 samples 4 from each of 2 pockets)											
(*Chemical* Analysis—2 samples one from each pocket)											
Green Hops											
Machine picked; at machine	46·2*	34·3*	80·5			13·3	3·5	2·7	6·2	—	
(Average 5 samples)	49·1	36·2	85·3	—	—	13·7				—	
	Average all Commercial dried samples		29·0 31·0			66·0 70·0				13·1 13·9	
				Average all dried samples			4·8	1·9	5·9		
				Average all green samples			3·5	2·7	6·2		

Source	lb./acre Green Hops	Estimated lb./acre Dried Hops
In Garden	Not Taken	
At machine		
1. Spent bines	†200	†40
2. Spent laterals	37	7
3. Fan waste	1,070	321
4. Sorters waste	5	1
Total unavoidable waste	1,112	329

NOTE: (*a*) Petal retained in hop sample so that Petal and Seed fraction not comparable with other machine series.

(*b*) The Wastage measured is not the total figure because (1) Waste in garden not taken. (2) No record taken of torn off laterals which accumulate after each trailer load and are put through machine while next trailer is coming up. Lateral Waste figure is, therefore, not comparable with the other machine series.

(*c*) Rate of loading—Hooks running at 15 per minute and every hook loaded. In 2 out of the 5 samples, only single strings were loaded, but in the others there were occasional doubles.

(*d*) Condition of hops—moist following week-end of rain and gales.

(*e*) Distance of transport to machine—1 mile.

* See *NOTE*—Table 1.

† Not included in total, since bine waste normally goes through mill and is included in fan waste. Wastage on bines was however, taken separately for comparison with the other machine series.

(3) Weight of waste from fan collected in a timed period (2 minutes).
(4) Samples of waste from fan for physical analysis to determine proportions of hop and waste.
(5) Amount of hop in rubbish thrown out by sorters in a timed period (3 minutes).
(6) Weight of separated petal collected in a timed period (2 minutes).
(7) Samples of separated petal for physical analysis to determine the proportions of hop (petal) and waste.
(8) Amount of hop left in garden after cutting bines.

Each whole series of samples at the machine was taken during a timed period of 3 minutes so that the wastage measured should be directly related to that particular sample of hops. The input of strings during each 3 minute period was also taken thus enabling the waste to be calculated as weight per acre of green hops. By using figures of relative moisture contents supplied by Mr. Watson of Wye College, these figures were converted into weight per acre of dried hops. Four or five replications of this series of samples were taken during the day. Wastage in the garden was measured by 8 replications of four-hill or nine-hill plots.

Hand

For the hand picking investigation comparable samples were obtained where appropriate. The hand picked hop samples were taken from several bins at the time of measuring. In the first series (A) this was done twice during the day and covered all the bins. In the second series (B) it was done once only on a sample of the bins. Wastage was, of course, confined to the garden only and was measured on the same basis as for machine picking.

*Photographs of Pocket Samples**

Finally, during the analysis of the pocket samples which was carried out in February and March, 1954, a series of colour photographs were taken showing:

(1) The side of pocket samples—hand and machine picked *ripe* Fuggles.

* It has not been possible to include the colour photographs in this paper, but some black-and-white reproductions will appear in a separate publication giving a general account of the information obtained from all the machine surveys carried out to date. The whole series of photographs is, however, available as colour slides.

(2) Four inside surfaces of each of the pocket samples above.

(3) The constituent portions of the same pocket samples after physical analysis. (The appearance of these samples can thus be related to the percentages of the constituent portions).

(4), (5), (6) The same subjects for hand and machine picked *over-ripe* Fuggles.

Results

The results are summarized in the attached Tables 1-5. These are:

Table 1.	Series A.	Hand picking.
Table 2.	,,	Machine (A) I.
Table 3.	,,	Machine (A) II.
Table 4.	Series B.	Hand picking.
Table 5.	,,	Machine (B).

In these tables all figures represent percentages by weight. Those in the left-hand (upper) columns represent percentages of the *total* samples, and those in the right-hand (lower) columns, percentages of the *hop portion* only.

Discussion

From these figures, two more tables (6 and 7) have been prepared to illustrate the two main comparisons defined as the aims of the investigation:

Table 6. Comparison of hand and machine picked dried hops and related wastage.

Table 7. Effects of picking and drying on breakage of hops.

Conclusions

This investigation provides the first quantitative data yet produced on the condition of samples of hand and machine picked hops through all stages from picking to pocket and measurements of the related wastage.

The figures obtained make possible several comparisons and bring out a number of important points. These will be considered in the order in which they have already been defined in the introduction.

1. *Comparison of Samples and Wastage*

Series A—Ripe Fuggles

(*a*) It can be seen that with good machine management and deliberate waste of petal a machine picked sample can be

TABLE 6

COMPARISON OF HAND AND MACHINE PICKED DRIED SAMPLES AND RELATED WASTAGE.

(Figures as percentages—in left-hand column percentages of Total Sample; in right-hand column percentages of Hop portion only.)

Commercial Sample compared with "Whole Hops; protected drying"	Good Ripe Fuggle				Poor Over-Ripe Fuggle			
	Hand		Machine A—Series I (Deliberate Waste of Petal)		Machine A—Series II (Deliberate Waste of Petal)		Hand		Machine B (Petal retained in Sample)	
Loss of Recognisable Hop ..	20·8	17·8	27·4	23·4	27·9	24·9	32·2	28·2	64·6	62·6
Gain in Petal and Seed	17·2	18·2	26·4	27·4	24·1	23·1	26·1	28·1	59·4	63·4
Loss of Total Soft Resin	1·5	1·1	2·4	2·1	1·1	0·6	2·4	1·5	3·3	2·5
Amount of Extraneous matter .. (Total leaf and Stem)	3·0	—	3·1	—	3·5	—	5·0	—	5·9	—
Total Wastage dried hops per acre	29		514		324		30		329*	

* This figure is known to be less than the total; it is probably about 30lb. too low.

produced which is very closely comparable with good hand picked samples. In order to obtain this result, however, a total wastage of the order of 3-5 cwt. per acre of dried hops is involved, of which about $1\frac{1}{2}$ cwt. per acre is deliberate. Hand picking, by comparison, wastes little more than $\frac{1}{4}$ cwt. per acre.

Although there is virtually no visible difference between the two types of sample in the pocket, there is in fact more loose seed in the machine picked sample because although petal can be blown out and thrown away, much of the seed from the broken hops remains behind.

TABLE 7

EFFECTS OF PICKING AND DRYING ON BREAKAGE OF HOPS.

As assessed by: (1) Loss of Recognizable Hop (RH).
(2) Gain in Petal and Seed (P and S).
(3) Loss of Total Soft Resin (TSR).

(Figures are percentages of Hop portion of sample only.)

Series A—Ripe Fuggle. *Good* Hand and Machine Picking

	Hand			Machine A—Series I (Deliberate Waste of Petal)			Machine A—Series II (Deliberate Waste of Petal)		
	Loss of RH	Gain in P and S	Loss of TSR	Loss of RH	Gain in P and S	Loss of TSR	Loss of RH	Gain in P and S	Loss of TSR
Total Damage—picking and drying (Commercial dried sample compared with "Whole Hop; protected drying")	17·8	18·2	1·1	23·4	27·4	2·1	24·9	25·9	1·0
Damage from *picking* (hand/machine picked; protected drying) ..	7·9	8·4	0·3	3·7	3·8	1·1	5·3	5·7	*
Damage from *drying only*	9·9	9·8	0·8	19·7	23·6	1·0	19·6	20·2	*

Series B—Over-Ripe Fuggle. *Poor* Hand and Machine Picking

Total Damage—picking and drying	28·2	28·1	1·5	62·6	63·4	2·5	—	—	—
Damage from *picking only*	19·7	22·8	*	9·4	10·6	1·1	—	—	—
Damage from *drying only*	8·5	5·3	*	53·2	52·8	1·4	—	—	—

* Reliable figures not available.

(*b*) A relationship between wastage and extraneous matter remaining in the sample emerges from the two series on the same machine. The second of these series wasted 190 lb. per acre dried hops *less* than the first, but it contained 0·4 per cent. *more* leaf and stem in the final sample.

Series B—Over-ripe Fuggles

(*a*) With inexperienced and less satisfactory machine management, and where the loose petal is retained in the sample, the hand and machine picked samples are not at all comparable, the machine picked sample being about twice as broken as the hand picked.

The visual appearance of the two samples is also markedly different, the hand picked sample showing more visible leaf owing to the larger size of the separate pieces and the machine picked sample showing large pieces of petiole (stem). (This is typical of the visible differences between hand and machine picked samples.)

(*b*) *Wastage.* In both hand and machine picked samples, wastage was higher than in the previous series. In the case of Machine (B) it is interesting to note that although the amount of leaf and stem in the final sample was nearly twice as great as in the case of the other Machine (A), the wastage of hops did not diminish in proportion.

This is a reflection of the different management. Machine A was using the "coat-hanger" system of transport of bines to machine and maintained continuous feeding. The hooks were running at 16 a minute but not all of these were loaded. The average rate of input of strings was in fact 11 or 12 per minute. Machine B was being fed by trailer loads of loose bines which were loaded on to the machine as fast as possible. The hooks were running at 15 a minute and every hook was normally loaded. If any were missed, two strings were loaded to make up for it and this was done occasionally even if no hooks were missed. In between trailer loads the loose laterals were collected and fed into the machine. Working was, therefore, very intermittent, the machine being overloaded at times and running under capacity at others. The angle of the "cascades" was also not adjusted for maximum efficiency.

Comparison of Points of Wastage on Machines

It is interesting to examine the amount of wastage occurring at different points on the machine.

Easily the greatest loss is in the fan waste and the most obvious means of reducing this would be to reduce the breakage of the hops to start with. It might be also possible to effect some improvement by mechanical adjustments and modifications.

The amount of hop left on the spent bines can also reach important proportions. Much of the "routine" wastage here is in the form of bare cone strigs from which all the petal has been knocked off. These, of course, are negligible, but the real wastage occurs when odd laterals or the "tail" of the head are missed completely by the picking loops. The owner of Machine A whose spent bine wastage was less than half that of Machine B, overcame this difficulty by having these "tails" cut off as the strings swung clear after loading, and then treated as laterals.

Although the wastage from spent laterals does not amount to very much per acre, in proportion to the total amount of hop originally on them it is very high. This fact, together with the severe breakage caused by the roller type of lateral picker suggests that the machine picking of laterals is the least satisfactory part of the whole process. All methods of avoiding the tearing off of laterals at any stage, therefore, warrant consideration and the desirability of making provision for these laterals to be picked by hand rather than accumulate on the machine, should not be overlooked.

2. *Effects of Picking and Drying*

Both Series A and B show clearly that the main breakage of machine picked hops occurs during the *drying* process. This is no doubt because the machine picked sample has a greater proportion of hops partly broken to start with and it is these which are further shattered during drying. This amount of partial breakage cannot be deduced from the category "recognizable hop" which is not relevant to this point. It is, however, seen in the physical analyses of the *green* samples where the more severe discrimination of what constitutes a "broken" hop is applied (see footnote to Table 1). Thus, the hand picked sample at the kiln in Series A has only about 20 per cent. of broken hops, whereas the two machine picked samples have 38 per cent. and 26 per cent. respectively. The figures for green hops in Series B do not show a similar difference, but this is partly accounted for by the later date of hand picking of the already over-ripe hops. The devastating effect of the drying process on the over-ripe machine picked hops is, however, clearly demonstrated, and suggests that bruising by the machine has a bad effect on the hops even though it may not break them at the time. In this context the "drying pro-

cess" includes re-loading the machine picked hops and transporting them to the oast, a distance of about 150 yards.

The result is of particular interest in connection with the controversy still unresolved among machine users, as to whether it is better to have the machine close to the garden or to the oast. The results of this investigation definitely support proximity to the oast since the above example indicates a high degree of damage *after* picking, whereas a comparison of the two series on Machine A show no deleterious effect of the long journey $\frac{3}{4}$ mile to the machine; this sample is in fact better than the one where the bines had a much shorter journey.

These results suggest that the amount of damage caused by reasonably good machine picking could become of little consequence if a new technique for drying were evolved which would cut out further handling and so minimize subsequent damage. (The application of such a new system would, of course, also benefit hand picked hops, although not to the same extent.)

The second point to be emphasized has been fully stressed in the West Midlands survey report, namely, the desirability of a succession of varieties to avoid having to pick any hops in an over-ripe condition.

3. *Subsidiary Comparisons*

(*a*) *Hand Picking.* Two points of interest relating to *hand picking* may also be deduced. Thus, it is possible to see that over-ripe Fuggles break up nearly twice as badly as do ripe Fuggles, even when hand picked. The extra damage caused by bagging and transport from the garden to kiln is also brought out; this may not be very material in the case of ripe hops, but with over ripe hops it is appreciable.

These points suggest that those growers who at present have only Fuggles and, therefore, are often obliged to pick some of them over-ripe would do well to consider a succession of varieties or at least of strains, even though they may have no intention of embarking on machine picking.

(*b*) *Chemical Analyses* (*Total Soft Resin*). These have not been referred to in the discussion since it is clear that they do not form a reliable method of comparison, except possibly between the two extremes of "whole hop; protected drying" and the commercial dried samples. This is no

doubt due to the fact that in dried samples there is always a certain amount of loose resin which may be present in disproportionate amounts in the small samples taken. In the case of machine picked hops, especially in wet weather, there is the additional factor of lumps of resin dropping off from the belts into the sample (see footnote to Table 3).

One point of interest does, however, emerge from the chemical analyses, namely that Fuggle N (Series B) is seen to have about 1 per cent. more total soft resin than the other strains of commercial Fuggle involved.

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This investigation represents the combined efforts of a large team. In addition to the two students provided by the A.R.C., four field assistants were borrowed from another department of the N.A.A.S. at Wye. Mr. J. R. Pearce, N.A.A.S. Machinery Adviser at Wye, helped consistently with the machine sampling and with some of the laboratory work and subsequent calculations. Mr. J. M. Merridew, Lecturer in Machinery at Wye College, also helped at times during the field and laboratory work, and very materially with the subsequent calculations. Mr. A. E. Maddison of Wye College approved the design of the investigation from a statistical angle, and undertook to do the statistical examination of the figures, although this has not yet been carried out. Two other N.A.A.S. Officers at Wye also contributed, Mr. G. Elis-Jones with calculations, and Mr. J. J. Walker who took the photographs. Mr. F. C. Thompson, Acting Head of the Department Hops of Research at Wye College, arranged for the Total Soft Resin analyses to be carried out by his staff. Finally thanks are due to the farmers for their co-operation and to the Hops Marketing Board for supplying the pocket samples.

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